

ESD TDR 64-234
Vol III
ESTI FILE COPY

D-TDR-64-234
VOL . III

ESD RECORD COPY

RETURN TO
SCIENTIFIC & TECHNICAL INFORMATION DIVISION
(ESTI), BUILDING 1211

COPY NR. _____ OF _____ COPIES

DESIGN AND USE OF INFORMATION SYSTEMS FOR AUTOMATED ON-THE-JOB TRAINING

VOLUME III

Experimental Use of Three Instructional Concepts

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-234

MARCH 1965

ESTI PROCESSED

☐ DDC TAB ☐ PROJ OFFICER

☐ ACCESSION MASTER FILE

☐ _____

DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

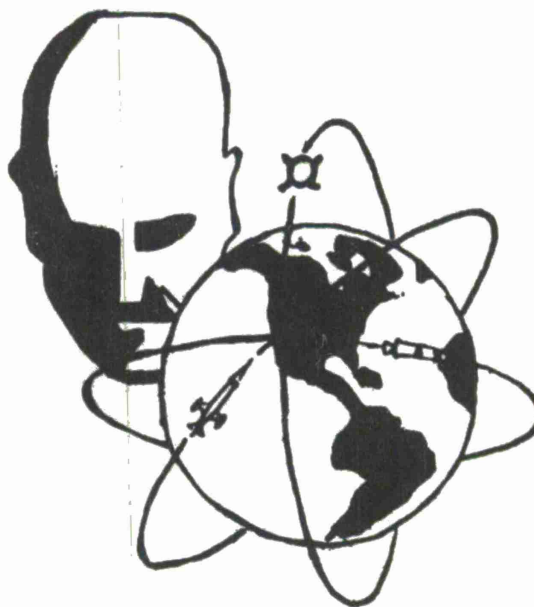
DATE _____

ESTI CONTROL NR. **AL** 46215

L. G. Hanscom Field, Bedford, Massachusetts

CY NR. 1 OF 1 CYS

ESKH



Project 7682, Task 768204

AD616544

(Prepared under Contract No. AF 19 (628)-455 by Bio-Dynamics Incorporated, Cambridge, Mass.)

DDC AVAILABILITY NOTICE

Copies have been deposited with the Defense Documentation Center. (DDC)

DISSEMINATION NOTICE

Copies available at the Clearing House for Federal Scientific & Technical Information. (CFSTI) (Formerly OTS)

LEGAL NOTICE

When US Government drawings, specifications or other data are used for any purpose other than a definitely related government procurement operation, the government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

OTHER NOTICES

Do not return this copy. Retain or destroy.

ESD-TDR-64-234
VOL . III

DESIGN AND USE OF INFORMATION SYSTEMS FOR
AUTOMATED ON-THE-JOB TRAINING

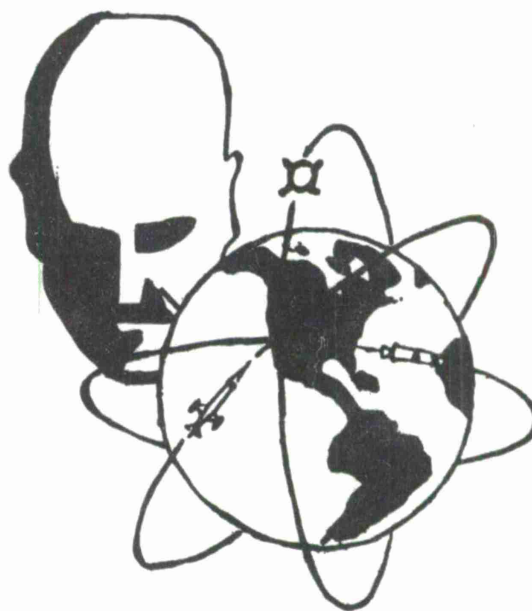
VOLUME III

Experimental Use of Three Instructional Concepts

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-234

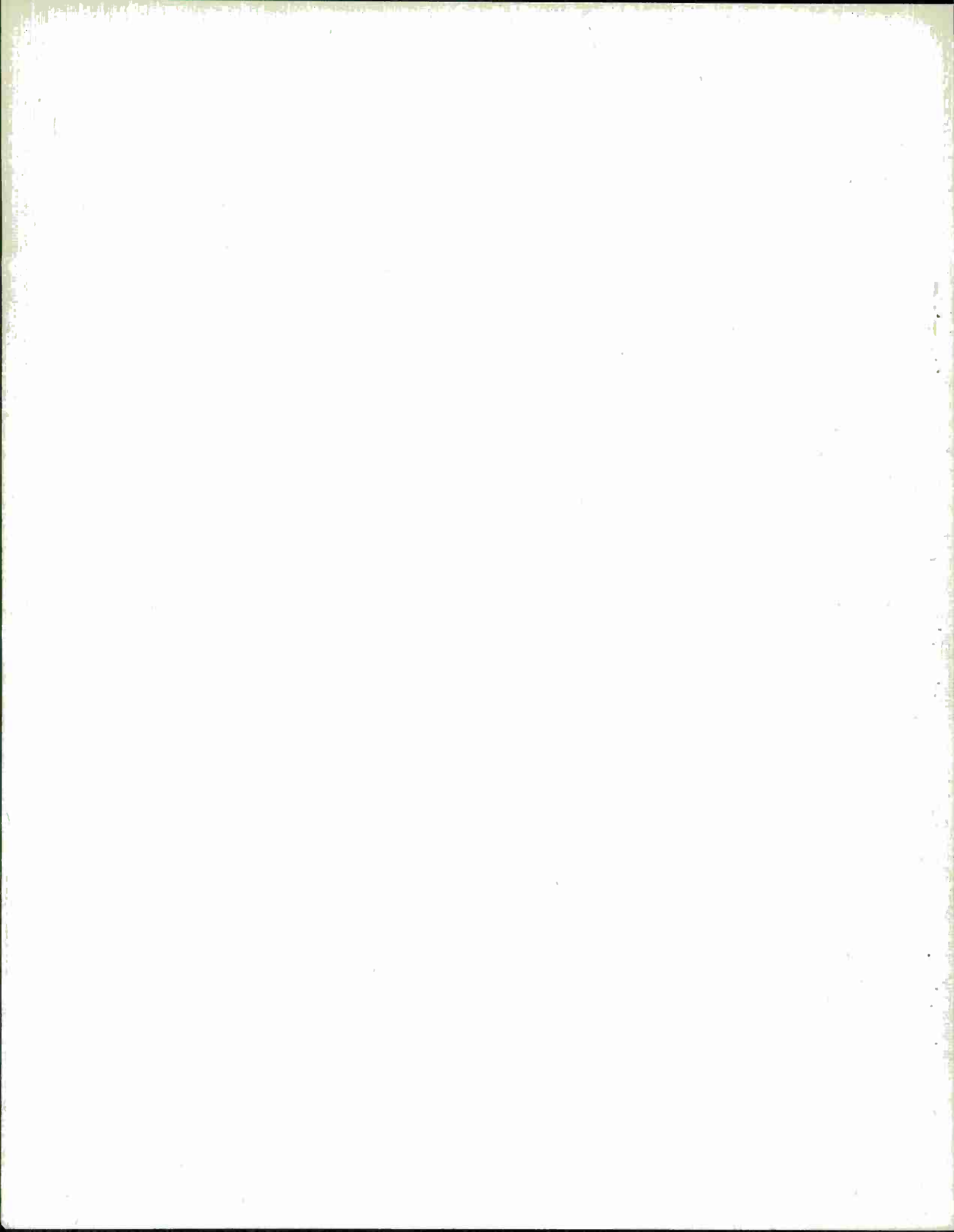
MARCH 1965

DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts



Project 7682, Task 768204

(Prepared under Contract No. AF 19 (628)-455 by Bio-Dynamics Incorporated, Cambridge, Mass.)



FOREWORD

One of the research goals of the Decision Sciences Laboratory is the development of design principles for automated training subsystems which could be built into future Information Systems. Such subsystems would provide Information Systems with the capability of training automatically their own operators. To be able to design such a capability requires first the solution of many conceptual and experimental problems. This report explores some programing concepts for the training materials in these systems.

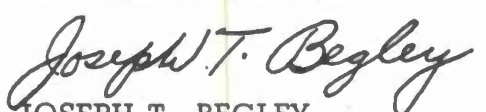
This report is one in a series supporting Task 768204, Automated Training for Information Systems, under Project 7682, Man-Computer Information Processing. The research was conducted during 1962 to 1964. The Principal Investigator was Dr. Thomas B. Sheridan and the Contract Monitor was Dr. Sylvia R. Mayer.

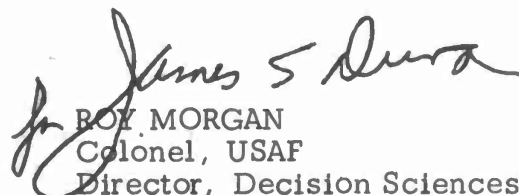
Several Bio-Dynamics' staff members have contributed directly to the accomplishment of different parts of this study: A. R. Johnson, J. Mickunas, and A. W. Mills to the experiment described in Chapter II, R. Rosenberg, H. Chamberlin, and B. C. Duggar to those described in Chapters III and IV.

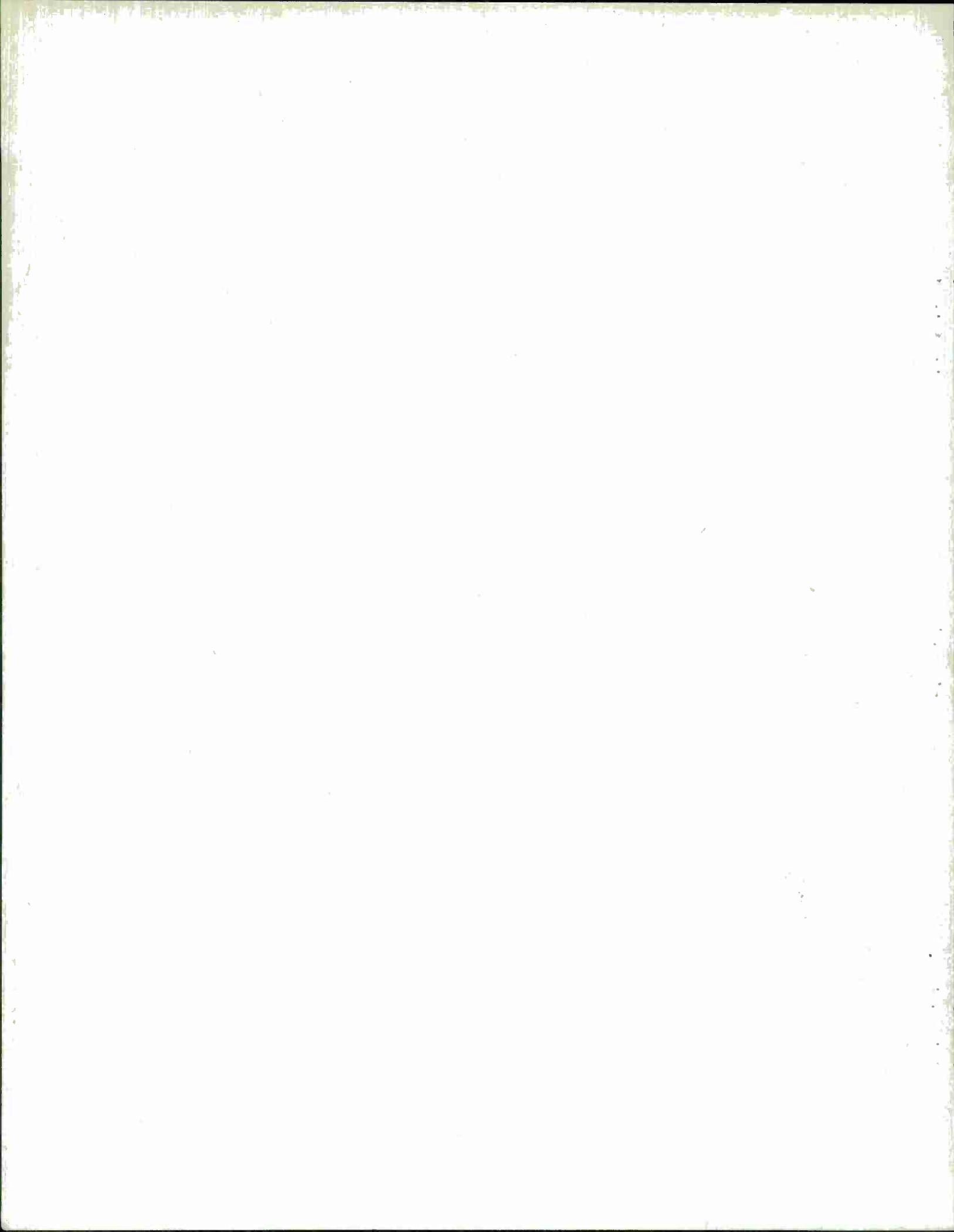
PUBLICATION REVIEW AND APPROVAL

This Technical Documentary Report has been reviewed and is approved.

FOR THE COMMANDER


JOSEPH T. BEGLEY
Chief, Applications Division
Decision Sciences Laboratory


ROY MORGAN
Colonel, USAF
Director, Decision Sciences Laboratory



EXPERIMENTAL USE OF THREE INSTRUCTION CONCEPTS

Abstract

This report describes three experiments in which novel teaching concepts were demonstrated. These concepts had been proposed in previous reports but their effectiveness remained to be verified experimentally.

The results were:

1. A teaching program ordered according to the discovery principle significantly reduced errors and performance time over that observed after training with a conventional training manual.
2. Slides projected directly onto a control console, together with a taped lecture, were found to be an effective method of presenting an automated training program.
3. Graphical logical flow diagrams were found to be efficient instructions for teaching procedures for performing a querying-reasoning task.

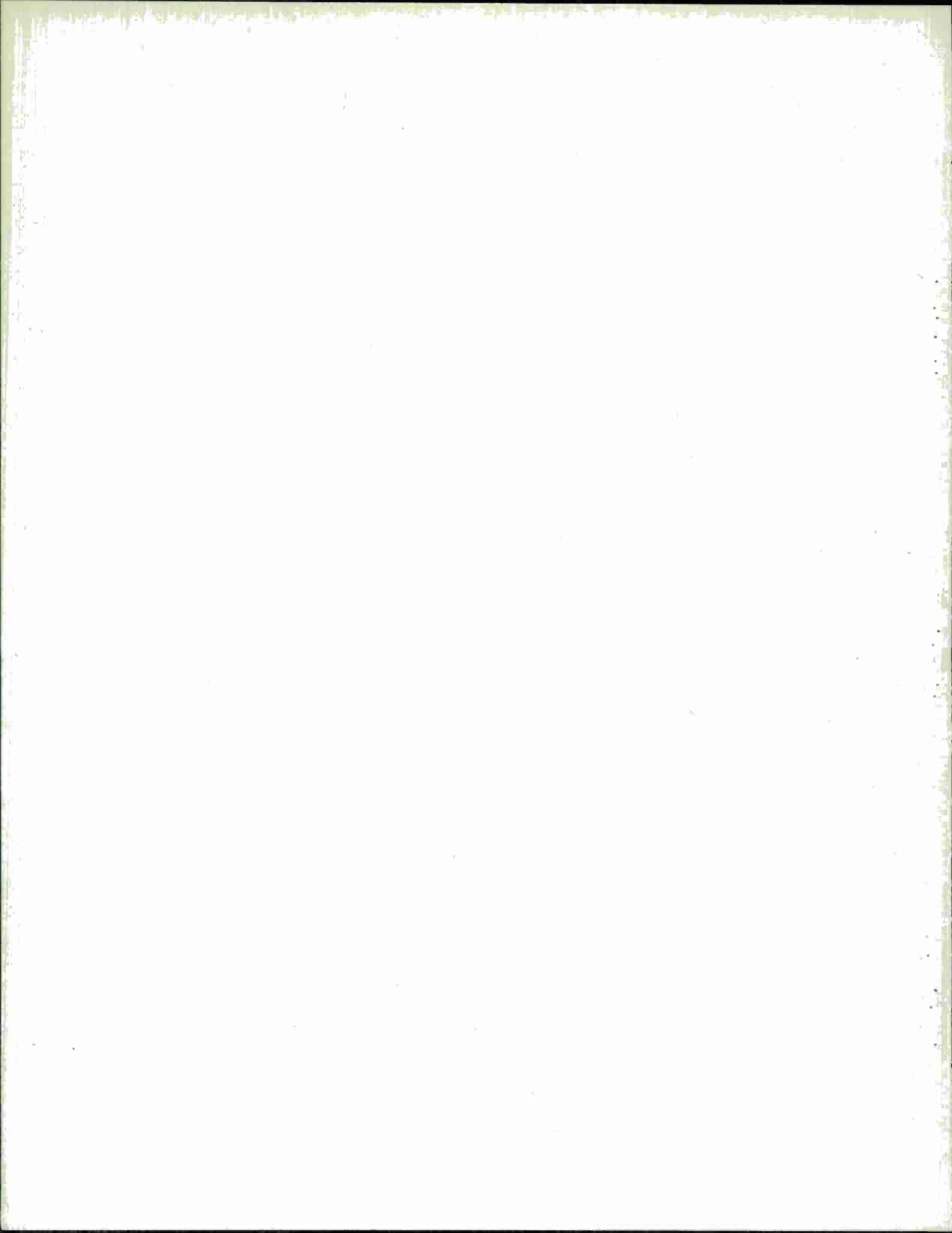
It was concluded that these concepts should be exploited in training programs for operators of Air Force Information Systems.

TABLE OF CONTENTS

	<u>Page</u>
I. INTRODUCTION	1
II. PHYLOGENIC TEACHING PROGRAM	3
A. Background	3
B. Experimental Design	5
C. Results	11
D. Discussion	15
III. PROJECTION EXPERIMENT	16
A. Background	16
B. Equipment	18
C. Subjects	20
D. Procedures	20
E. Results	22
F. Discussion	24
IV. INSTRUCTION IN QUERYING-REASONING BEHAVIOR	25
A. Background	25
B. Experimental Design	26
C. Results	34
D. Discussion	34
V. APPLICATION CONSIDERATIONS	37
VI. CONCLUSIONS AND RECOMMENDATIONS	40
VII. REFERENCES	42
APPENDICES	
A Instruction Manual for Operation of the Lissajous Figures Control Console	43
B Instructions for the Phylogenic Teaching Program	59
C Instructions for the Verbal Analysis Teaching Program	61
D Individual Performance Measures for the Lissajous Figure Control Console Experiment	63
E Instructions for Slide and Tape SAGE Console Task Teaching Program	64

TABLE OF CONTENTS (Continued)

	<u>Page</u>
F Instruction Manual for SAGE Console Task	67
G Instruction Manual for the Numbers Game	69
H Performance Measures for the Numbers Game	73



LIST OF FIGURES

	<u>Page</u>
Figure 1 Console with two identical sets of 12 control functions.	6
Figure 2 Abstract representation of SAGE IND Director's console.	19
Figure 3 Bookkeeping sheet for the numbers game.	28
Figure 4 Over-all task diagram	30
Figure 5 Level 2 diagram	30
Figure 6 Level 2 diagrams	31
Figure 7 Level 2 diagram	32
Figure 8 Level 3 diagrams	32

LIST OF TABLES

	<u>Page</u>
Table 1 Mean performance data for all subjects who completed training	13
Table 2 Mean performance data for matched groups of subjects	13
Table 3 Mean performance data for the console test	22
Table 4 Median performance data for a querying-reasoning test	35

I. INTRODUCTION

The experiments described in this report were performed as part of a research program to develop general principles for the design and use of Information Systems for automated on-the-job training. The experiments were designed to validate new instructional techniques or principles which had been mentioned in earlier reports of this series (1, 2). These methods and techniques are believed to have application for the training of operators of future Air Force Information Systems.

There exists a large body of literature on learning theory, but relatively little attention has been directed towards providing principles directly applicable to the tactical issue of how best to teach particular skills (3). Questions relating to program order, frame size, verbal versus symbolic content, presentation techniques, etc., remain as impediments to the specification of system requirements for inclusion of automated training capabilities. New methods and techniques can be derived which are in accord with current theory and which offer advantages in ease of implementation but because of uncertainties, experimental validation is mandatory; for example, the efficiency with which they teach the required skills or knowledge must be demonstrated.

The first experiment (Section II) is an evaluation of a teaching program ordered according to the "discovery" principle. In this program, the trainee is led to discover the need for each control function before the control device is introduced to him. Thus, the trainee invents a system which meets the perceived task needs. As more and more functions are added, the aboriginal system progresses through a "phylogenic" evolution until it reaches the final,

sophisticated state. The "discovery" or "phylogenic" teaching concept was described more fully in a previous report (1), and is believed to be particularly useful for instruction in the use of multiple control functions and as a means of ordering teaching programs whose content does not suggest a logical order.

Section III contains a description of an experiment in which graphical logic flow diagrams were projected directly onto an abstract representation of a SAGE console. A taped lecture accompanied the series of 15 slides and provided a program for instructing trainees in the use of console control sequences. This experiment served two purposes: first, the demonstration of a teaching technique using the operational equipment but requiring no modification to the equipment, and second, the demonstration of the use of logic flow diagrams as teaching or user aids.

The third experiment (Section IV) involved instruction in querying-reasoning behavior, the use of bookkeeping aids, and the substitution of diagrammatic task descriptions for verbal descriptions in an instructional program. The development of a logic flow diagramming technique for use as a teaching aid is described in detail in another report (4). The validation of this technique for teaching querying-reasoning behavior together with its use in the experiment for teaching sequential use of console controls suggests that broad areas of application are feasible.

The system design implications of the three experiments are discussed in Section V of this report. The three areas studied: (a) teaching the functions of controls and how to apply them analytically, (b) teaching

the sequential use of controls and the logical relationships between sequences and mission developments, and (c) teaching querying-reasoning and bookkeeping skills, may overlap in the tasks required of future Air Force Information Systems operators. Suggestions for combining the various techniques in teaching programs are included in Section V.

II. PHYLOGENIC TEACHING PROGRAM

A. Background

The introduction of a naive trainee to his future role as operator of a complex system requires not so much the establishment of a pattern of rote responses but rather the instillation within him of the functional purposes of the displays and controls to which he has access. Therefore, it is the meaning or semantic content of each component at his interface with the system that must be learned. Unfortunately, this information is often conveyed to him in a language in which he may initially have no fluency. It is postulated that the elicitation of an insight on the part of the trainee for the need for a new function, before that function has been presented or even described to him, will produce the most rapid, retrievable, useful, and comprehensive learning.

If we are to provide a training program which will render the operation of the system self-teaching, then we must consider the problem of stimulus-response format so that sequential insights into its functions will be induced. We shall ignore for the moment the language problem by allowing a person to communicate with the subject according to pre-specified rules.

An alternative description of the role of the trainee would characterize him as the inventor of the system as, step by step, he calls for new component functions to improve the capabilities of the system. In order to promote the most rapid "invention" of the desired system, problem situations are presented sequentially to be solved through use of the system itself. Note that the trainee need not specify the physical form of the device but only its function or purpose. The desired function having been verbalized adequately, an appropriate system component is made available to the trainee for immediate use and confirmation.

It is apparent that a favorable starting point for training program development is to be found in the former evolution of the system itself. For this reason, the approach to operator training being described here has been termed the "Phylogenic Method" in that the inventor-trainee causes the system to proceed in its development through the various "phyla" in the system's evolution (hypothetical or real).

Rigid adherence to the sequence of actual system changes is impossible since, on the one hand, it would be very difficult to identify a precise course of system evolution, and on the other, it is advantageous to let the variable insights of the individual trainee adapt the program to the order of development which is most appropriate for him. A more extensive discussion of the theoretical development of the phylogenic method may be found in reference 1.

A test system was fabricated for the comparison of the phylogenic method with other, more standard methods. It consisted of a panel of

controls which could be used to manipulate characteristics of Lissajous figures on an oscilloscope screen to make them match the desired figure as presented on a transparent overlay. The sequence of overlays presented was the teaching program.

Initially, it was planned only to compare the teaching performance of two alternative methods: a phylogenic ordered program, and an instruction course using a written manual and practice exercises. The results of this comparison were sufficiently interesting to warrant the addition of two modified teaching programs: (a) a phylogenic ordered program in which the trainee had no physical contact with the console, and (b) modifying the written instruction manual to include a series of practice exercises which precisely duplicated those used with the phylogenic program.

B. Experimental Design

1. Equipment

The console and display are shown in Figure 1. The console face was a flat panel having 24 holes, each showing a color coded shaft or toggle just out of reach. Color coded knobs and shaft extensions were provided individually when the designated control function was ready to be used during the phylogenic program, or were already in place for the manual. The various control functions were divided into two identical sets of 12 each. Each set of functions could be applied to one of the two Lissajous figures which appeared singly or simultaneously on the display screen. The control functions were:

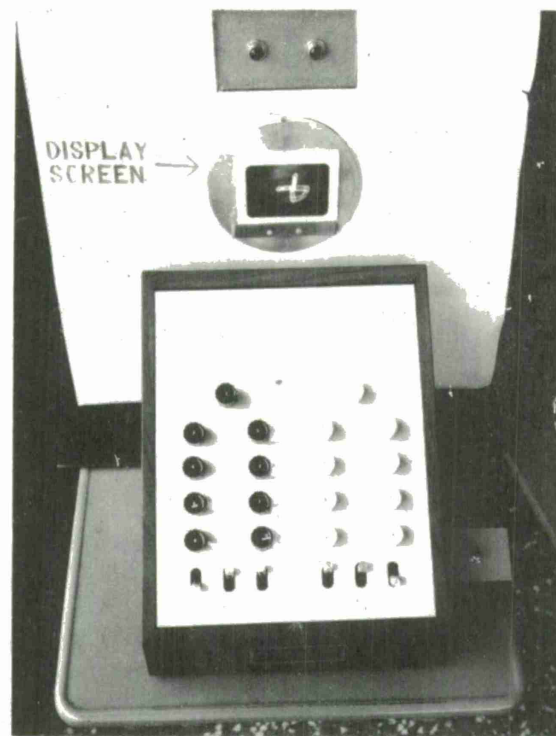


Figure 1. Console with two identical sets of 12 control functions. Controls are used to produce Lissajous figures similar to that shown on display screen above the console.

1. on-off switch for the particular figure
2. right-left movement
3. up-down movement
4. amplitude change along the x-axis
5. amplitude change along the y-axis
6. phase shift function common to both x and y-axes
7. partial limiting along y-axis
8. partial limiting along x-axis
9. vertical line width
10. horizontal line width
11. vertical mirror-image function
12. horizontal mirror-image function

The display consisted of a 5-inch CRT on which one or two Lissajous figures could be created. A slide holder was fitted to the face of the CRT so that 3 x 4 inch transparencies could be placed between the observer and the display screen. The opacity of the transparencies was low and did not obscure the view of the Lissajous figures. Consequently, the viewer could compare the characteristics of the Lissajous figure with whatever figure appeared on the transparency, and by manipulating controls cause the two to coincide (see Figure 1).

Beside the console was a button which the trainee used to signal completion of each slide. If the match between slide and Lissajous figure(s) was acceptable, a green light over the display went on. If not, a red light went on. The experimenter was separated from the subject by a panel,

but could observe both the display and the control console through a small aperture.

Control knob and completion button use were recorded on a 33-channel event recorder. The event record served as the data source for subsequent performance analyses.

2. Subjects

Subjects were 28 paid male college students who responded to an advertisement on the student aid bulletin board. Subjects were divided into 7 matched groups on the basis of results on the Revised Minnesota Paper Form Board Test (MPT), Series AA. This test was administered when subjects were first contacted. The experimental sessions were then scheduled for a later date with members of each matched group assigned randomly among the four training programs.

3. Procedures

a. Instruction Manual (Short)

Subjects worked alone during the training period until they had completed going through the manual and 15 practice slides (the complete manual appears in Appendix A). The manual described each function, showed graphically how the function affected a figure, and included a sequence of functions needed to solve each of the 15 sample problems. The console was initially set up with all control knobs in place and descriptive diagrams of the control function located next to each knob.

b. Instruction Manual (Long)

Procedures were the same as for the short program with

the instruction manual, except that 80 practice slides were used. The practice slides were the same, and in the same order, as those used with the phylogenic program.

c. Phylogenic

Subjects were seated before the console which was without knobs or diagrams, and given a typed set of instructions (see Appendix B). The instructions described the task to be performed (match the figures on the CRT to those on the slides) and advised the subject on how to request necessary control functions, how to install control knobs, and how to signal completion of a problem. When the subject had read the instructions, the experimenter exposed the first slide and the training program began. The subject had to analyze the difference between the initial and goal figures and decide (or discover) what function(s) was needed. If a knob for that function(s) had not previously been received, the subject asked for the function (for example, "I need to be able to move it to the left"). If the request was appropriate to the problem, a color coded knob came down a chute and was then installed by the subject. At the same time, the subject was allowed to remove the mask over the diagram next to that control knob. If the subject asked for a function which was not a part of the equipment, or a function which was not needed at that time, the experimenter showed him a typed message "Your request cannot be provided at this time. Request a different control." In the case when the subject had enough controls to change the display figures, but asked for additional controls, the experimenter showed him another typed message "You have

enough controls already. "

When the subject finished training on single Lissajous figure displays (60 figures), he had acquired a complete set of controls for the left panel of the console. Before proceeding with double Lissajous figure displays, the subject rested for five minutes. Then, he was instructed that he would now learn to control two figures (see Appendix B) and was provided with all of the second set of controls. The subject then worked through 20 more practice studies, after which the training was complete.

d. Verbal Analysis

Procedures for the verbal analysis modification of the phylogenic program were only different in that the subject had no physical contact with the control panel. The program consisted of the same series of Lissajous figure displays as the phylogenic training program. Instead of analyzing the figure displays and manipulating the controls, the subjects had to verbalize their analyses and tell the experimenter what functions to use to change the display figure on the oscilloscope screen. The console was completely concealed from the subject during the training program. In place of the console was a panel on which were taped 12 blank 3 x 5 inch cards. Each time the subject correctly requested a new control function, one of the 3 x 5 inch cards was removed from the panel, exposing a description and diagram of the control function. The control diagrams and descriptions were in the same relative positions as on the actual console. The instructions for the verbal analysis program appear in Appendix C.

After completing the training and before the test, the subjects were shown the console and given 10 minutes to practice using the functions that they had previously learned.

e. Test

Subjects from all four groups were given the same test, consisting of 11 single figure problems (slides) and 9 double figure problems. The same set of instructions was given all subjects and the console arrangement was identical in each case. All knobs were in place and diagrams of the control function appeared next to each control. All control uses were recorded during the test.

Performance measures consisted of: (1) training time, (2) time to complete the test series (individual slide and total time), (3) frequency of use of inappropriate control, (4) errors in adjustment of appropriate control. Each test slide was analyzed and the necessary control functions listed. Since all control functions were independently controlled by their corresponding knobs, each had only to be used once. Successive uses, after the first, for an appropriate control were classed as "adjustment errors". As long as the subject continued to manipulate the same control, it was counted as a single application.

Subjects who did not complete at least the single figure slides in their instruction program within three hours were discharged and not given the test.

C. Results

Individual measures obtained from each subject are tabulated in

Appendix D. Complete experimental measures were obtained from only 25 subjects. Two subjects could not finish the verbal analysis training program within the three-hour limit, and one subject could not finish the phylogenic training program. Because the three subjects who could not cope with the training programs had scores among the lower third of those measured with the Revised Minnesota Paper Form Board Test, their performance was not considered sufficient reason for invalidating the phylogenic teaching concept. With the long instruction manual program, the Spearman rank correlation between high training time and low score on the MPT was significant at the 5 percent level ($r_s = 0.78$) as was the correlation with test time ($r_s = 0.74$). Short instruction manual time correlations with score were in the same direction but were not statistically significant ($r_s = 0.16$ and 0.45 , respectively).

Among those subjects who successfully completed the instruction programs, test time and number of both types of errors were smaller after the phylogenic or the verbal analysis program than after either of the instruction manual programs (Table 1). When the subjects were arranged into matched groups of 5 subjects each, using the MPT, the two phylogenic programs remained superior (Table 2). Analyses of variance were conducted on the five subject groups data, and Newman-Keuls sequential range tests were used to compare the differences among individual means (5). Differences between training time and between number of errors in control selection were found to be significant at the 5 percent level ($F = 4.4$

Table 1

Mean Performance Data
for All Subjects Who Completed Training (N = 7)

	<u>Phylogenic Instruction Program</u>		<u>Instruction Manual</u>	
	<u>Console</u>	<u>Verbal Analysis</u>	<u>Short</u>	<u>Long</u>
Training Time (min.)	60.6*	75.4**	72.0	103.0
Testing Time (min.)	28.0*	26.4**	48.0	41.0
Errors in Control Selection	64.0*	36.2**	119.0	105.0
Errors in Control Adjustment	176.0*	75.0**	293.0	248.0

*One subject did not finish training within 3 hours and was discharged; results are not included in group means.

**Two subjects did not finish training within 3 hours and were discharged; results are not included in group means.

Table 2

Mean Performance Data
for Matched Groups of Subjects (N = 5)

	<u>Phylogenic Instruction Program</u>		<u>Instruction Manual</u>	
	<u>Console</u>	<u>Verbal Analysis</u>	<u>Short</u>	<u>Long</u>
Training Time (min.)	58.5	75.4	72.7	89.2
Testing Time (min.)	25.6	26.4	37.2	34.2
Errors in Control Selection	58.0	36.2	123.2	115.4
Errors in Control Adjustment	120.6	75.0	291.2	280.8

and $F = 4.3$ with 3, 12 d.f.). The mean training time with the phylogenic program was significantly less than with the long form of instruction manual, and the mean number of errors with the verbal analysis program was significantly less than with either version of the instruction manual.

Analyses of variance were used to compare the results between the two discovery programs (phylogenic and verbal analysis). No statistically significant differences in performance were found. When the results with the two instruction manuals were compared with one another using seven matched pairs of subjects, only the difference in training time was found to be significant ($F = 7.289$ with 1, 6 d.f.). The results with the two discovery programs were then pooled ($n = 10$), as were the results with the two instruction manual programs ($n = 10$), and a variety of statistical comparisons between discovery and instruction manual programs computed. Differences in testing time, selection error, and adjustment error were all significant at the 1 percent level or better, but training time did not differ significantly between the two pooled groups.

The results of the phylogenic console program were also compared with the results of the two instruction manual programs using three matched groups of six subjects each. Training time was found to be significantly less with the phylogenic program (P less than 0.025) when the square root transforms were compared. Test time, and both types of error were significantly less with the phylogenic program (P less than 0.05 and 0.025, respectively).

D. Discussion

The experimental results indicate a clear superiority for the discovery principle teaching programs as opposed to conventional instruction manuals when given to subjects having a good ability to perceive spatial relations. Moreover, it is likely that the spatial relations' restriction was due primarily to the nature of the specific task used, and not to the teaching techniques.

Large differences in both speed and accuracy of performance on the test task were observed between the groups of subjects who spent roughly comparable periods of time learning by the several methods. A number of hypotheses have been considered to explain these differences. The hypothesis which seems most attractive is a comparison with linear and branched programmed instruction. The instruction manual method is similar to a linear program in that information is presented in a single, pre-determined sequence. The reader may skip while using the instruction manual, but he has no external guide as to when or how to skip, and can skip advantageously only after he had nearly mastered the material. In branching programmed instruction, the future program is contingent upon the past behavior of the student. At pre-selected points, the student is directed to a more advanced sub-program which de-emphasizes the particular aspects of the task over which he has already demonstrated his mastery. The phylogenic program may act as an inherently branching type of program in which the student determines the number and location of the branches.

According to this hypothesis, as the student invents the new functions required by the more difficult problems, he continues to use the more elementary functions invented earlier, but in an increasingly routine and perfunctory way. His attention is directed to those aspects of the task which he does not understand, and away from rehearsing what has already been mastered. The phylogenic method may be likened to a program of instruction with an indefinite number of branches occurring at an indefinite number of points, the program created by each student being uniquely adapted to his individual requirements.

Use of an instructor for teaching the experimental task was not evaluated. (Recall that the role the experimenter played in the phylogenic experiment was that of a mechanical language interpreter, not an instructor.) An instructor might lead his students to "discover" the need for each control function, or might simply review the material provided in the instruction manual. The fact that subjects did not have to physically use the controls to "discover" and learn their functions was illustrated by the performance of the verbal analysis group. Further research to determine if the discovery principle could be implemented in a written instruction manual appears to be warranted. Such an instruction manual would still be similar to a linear program, but the wording and format would be markedly different from that conventionally used in instruction manuals.

III. PROJECTION EXPERIMENT

A. Background

Training films have been used as teaching aids for many years.

However, the effectiveness of training films is limited, they are expensive to produce, and they lack flexibility. It is hypothesized that poor transfer from the film to the practice situation is a major limitation on the effectiveness of training films for console-type tasks. A method is needed whereby the same, or better, information can be presented to a trainee while he is seated at an actual console, and which requires that he make active responses, provides feedback for knowledge of results, and provides reinforcement. The method should be amenable to computer control and the presentation materials should be inexpensive to produce.

A previous experiment had demonstrated the effectiveness of logic diagrams as a teaching and user aid when printed on a console control panel. However, for complex tasks, the number of intersecting and overlapping diagrams could prove confusing. It is hypothesized that most complex console tasks can be broken into distinct, separate sequences of actions, each of which can be successfully diagrammed on the console control panel. Photo-projection of these diagrams, one at a time, onto the actual operational console face (as individual frames of a programmed course) together with displays of contingent or background information should permit the student to work through problems in a realistic fashion. Active responses could be required, knowledge of results and response reinforcement provided, and the program could be placed under computer or trainee control.

To demonstrate the feasibility of using such a technique for teaching purposes, an experiment was carried out. Projection diagrams and

information were keyed to a taped lecture and used to teach console operators to perform a simulated mission. For comparison purposes, another group of console operators received their training from an instruction manual.

B. Equipment

1. Console

The console was an abstract representation of an Air Force SAGE Intercept Director's console. Figure 2 shows the arrangement of the operator's station. On the center panel is the display, consisting of a 5 x 5 matrix of lights, and above the lights is a sequence diagram of all the possible display patterns in the simulated mission. On the left panel is a number of pushbuttons, surrounded by colored patches. The right panel was not used in this experiment. A detailed account of the development of the abstract console has been presented elsewhere (1).

Display patterns on the matrix of lights were controlled by the experimenter by means of a remote control box. Through the control box, the experimenter could select the order of the displays and advance the displays through the pre-selected sequence. Each display change was accompanied by some very audible mechanical noise which precluded the possibility of a subject not observing the display change.

The console pushbuttons were grouped by function category (all radio controls in one group, clear computer buttons in another group, etc.) and order of button pushing proceeded from left to right or from top to bottom across the panel.

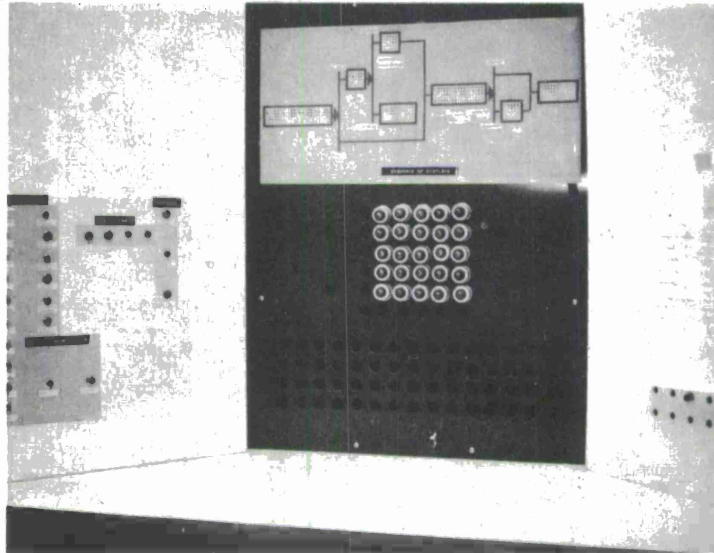


Figure 2. Abstract representation of SAGE IND Director's console.

One or two word descriptions of the function of each control button group and separate labels for each button were lettered on the console.

Approximately two square feet of area on the console face was available solely for the display of projected information. In addition, information and diagrams could be projected onto the button area.

2. Training Materials

A view-graph projector was used to project a series of slides onto the console face. Slides were constructed by drawing diagrams with a grease pencil and by typing legends onto transparent acetate sheets. The unused portions of the slides were masked off and positioning guides affixed to the projector. In most instances, information was projected both onto the area above the buttons and onto the button area as well. An explanatory lecture was recorded on a tape recorder and played back through a speaker located behind the console. Slide changes were keyed to the lecture material.

C. Subjects

Subjects were paid college students who responded to a notice on the student employment bulletin board. Twelve subjects were randomly assigned to either of the two treatment groups.

D. Procedures

1. Projected/Taped Instruction

Subjects were seated before the console and told that they would now listen to a taped set of instructions. The instructions described what the task was about, what was expected of the trainee, the nature of

the training course, and the test which would follow (see Appendix E for a more detailed description of the instructions and course material). A slide was then projected on the console and the taped instructions continued. The slides and tape directed the trainee through a series of sequences on the console (which was turned off). Thus, nothing happened when the trainee pushed the buttons on the console during practice and the console display was blank. Representations of the live displays were projected corresponding to each sequence. Additional information was presented which described the nature of each sequence, told the operator how to perform the sequence, then told him to follow the diagram through the sequences pushing the designated buttons. After all sequences had been viewed, they were reviewed.

After completion of the training course (which took 24 minutes), the subjects were given a ten-minute rest. Subjects then returned to the console and were told that their proficiency would be tested during several simulated intercept missions. The instructions were to work as rapidly as possible, but without making errors. The console was turned on, the first display appeared, and the subject was on his own. If the button sequence for each display was correctly performed, the display changed and the mission proceeded. If the subject made a mistake during a sequence, the display would not change and the subject had to figure out what the correct sequence should be. He could try as many alternative sequences as he wished, but all errors were recorded. Three simulated missions were performed. Total time and number and type of errors were recorded.

2. Instruction Manual

Subjects were seated before the console, given an instruction manual and a set of introductory instructions. The instructions described the nature of the task and told the subject that he was to study the instruction manual and the console. When the subject signaled that he was through studying, he was tested during several simulated intercept missions. The instructions and manual are described in greater detail in Appendix F.

Performance measures consisted of training time, time to successfully complete each of three simulated intercept missions, and errors. The errors were classified as either (a) an action sequence inappropriate for the display sequence, or (b) an incorrect action (button) within a correct sequence.

E. Results

Mean performance data for each of the groups with each of the three test simulated missions appear in Table 3. With the exception of training time, none of the differences between groups was statistically significant. When the individual training times were compared to the median training time for all 12 subjects and evaluated by the Fisher exact probability test (6), the training times with the slides and tape were found to be smaller significantly often (P less than 0.04). One subject in each of the groups successfully completed all test missions with no more than one error. On the third test mission, four of the subjects who were trained by the slides and tape method and five of the subjects trained by the instruction manual method made no errors.

Table 3

Mean Performance Data
for Console Test (N = 6)

	<u>Training Time (min.)</u>	<u>Errors Display Sequence</u>	<u>Button</u>	<u>Test Time (min.)</u>
1. Instruction Manual	45.4			
(a) Test Mission I		0.7	1.3	3.8
(b) Test Mission II		2.8	5.7	4.0
(c) Test Mission III		<u>0.3</u>	<u>0.8</u>	<u>1.6</u>
Mean, all missions combined		3.8	7.8	9.5
2. Slides and Tape	24.0			
(a) Test Mission I		2.5	4.3	3.6
(b) Test Mission II		3.0	8.0	4.2
(c) Test Mission III		<u>0.2</u>	<u>0.3</u>	<u>1.3</u>
Mean, all missions combined		5.7	12.7	9.1

F. Discussion

Although films, slides, or taped voice instruction and user aid programs have been previously used in variety of ways, we believe that this experiment demonstrates a novel application which could be easily implemented for use with simple equipment consoles, or even with complex computer-based system consoles. Computers have already been used to control presentation of slides containing instruction materials (6), or to generate displays in a computer-directed teaching program (7). Evaluation of results, reinforcement, and selection of program branches have been performed by a computer in these systems. A more simple decision structure has even been programed into a tape recorder to control verbal instruction sequences (9). The Smiths Aural Diagnostic Inspection Equipment (SADIE) guides the user through a check-out routine on electronic equipment based on yes-no repeat responses to taped action-question instructions. The decision structure for SADIE is similar to that expressed in man-machine graphical logic flow diagrams (Section IV). Another system, the Automated Diagnostic Maintenance Information Retrieval System (ADMIRE) uses a library of instruction slides to guide maintenance and check-out sequences (10). However, integration of instruction display with operational controls has not been used in an automated instruction program, or as a user aid.

During the instruction period with the slides and taped lecture, none of the subjects was observed to take inappropriate actions. It would, therefore, appear useful to provide console operators with a library of

action sequence diagrams corresponding to the more common and even some important uncommon display conditions. These diagrams could be projected directly onto the operational console control panel, and additional contextual information displayed on an adjoining screen. Operator training would then emphasize display interpretation and how to follow action sequence diagrams, and would not emphasize rote memorization of action sequences.

In this experiment, subjects who used the instruction manual were allowed to spend as little or as much time as they felt necessary to study the manual and the console. Subjects who heard the tape and viewed the slides did not have this opportunity. Although the instruction manual group did spend more time studying, it is not known whether their performance would have been significantly worse had they been restricted to only 24 minutes.

IV. INSTRUCTION IN QUERYING-REASONING BEHAVIOR

A. Background

The development of hypotheses, testing of hypotheses, and the evaluation of results in a decision context will characterize the behavior of some users of future Air Force Information Systems. Verbal explanations of the relationships between diverging and converging sequences of task cycles (hypothesis development-testing-evaluation) are often cumbersome. Graphical representation of the logical contingencies governing branching paths may provide a description of the relationships among

decisions and of sub-goals to system objectives. However, the effectiveness of such graphical representations for teaching purposes, without accompanying lecture or text, remains to be demonstrated.

The experiment described in this section of the report was performed to demonstrate that graphical logic flow diagrams can serve as sufficient and efficient instructions for a querying-reasoning task. The symbology and a methodology for diagraming man-machine tasks have been described in detail elsewhere (4). Graphical logic flow diagrams have been used successfully as performance aids with man-machine tasks characterized by display interpretation and contingencies among sequences of action. Computer program flow diagrams have been used to guide programmers, computation analysts, and even digital computers. The use of a diagrammatic symbology as the teaching program language for a querying-reasoning type task represents an attempt to show the breadth of application for such a language.

B. Experimental Design

1. Task Description

The task selected for this experiment was the "numbers game" described in an earlier report (1). The subject's task in the numbers game was to determine an unknown four-digit number. The experimenter simulated an information system which the subject used in solving the problem. The subject queried the information system by selecting a four-digit test number from a list of 30 test numbers and requesting a score

for the selected test number. The score denoted the number of digits in the test number which were identical in value and position to those of the experimenter's number. By a process of logical deduction and rigorous bookkeeping of the results of each scored test number, it was possible to determine the unknown number. The number of test numbers (queries) required varied inversely with the amount of information that the subject extracted from each successive score. Since all test numbers would not produce identical amounts of information, the subject had to select them sequentially according to previous results and reasoning.

2. Subjects

Twelve college students served as paid experimental subjects. Subjects were randomly assigned to either of two groups, each of which received different instruction programs.

3. Instruction Programs

Two different methods were employed to teach the subjects the nature of the game, optimum strategy, and the bookkeeping procedures which should be used. Both methods were centered around teaching the use of a "bookkeeping" sheet developed in previous experiments with the game (1). This bookkeeping sheet (see Figure 3) contained: (1) the list of test numbers (LTN), (2) a Score Register (SR) in which the subject was to enter numbers with at least one correct digit (score greater than zero), and (3) a Possible Digits Register (PDR) in which the subject would cross out digits which had been eliminated as possibilities.

Code	Digits	Score
------	--------	-------

1	3	1	0	2	
2	2	7	8	8	
✓ 3	9	0	0	7	0
✓ 4	1	5	6	4	0
✓ 5	1	0	3	4	0
6	7	8	9	2	
✓ 7	9	3	4	2	2
8	8	2	2	8	
✓ 9	4	2	1	9	0
10	0	9	6	5	
✓ 11	6	4	8	6	0
12	3	2	5	1	
13	5	9	6	7	
✓ 14	6	3	0	9	1
15	4	5	9	5	
16	2	0	5	0	
17	7	1	2	3	
18	1	9	7	1	
19	7	1	3	7	
✓ 20	3	7	7	9	0
✓ 21	5	3	4	6	2
22	6	8	5	0	
23	4	6	8	1	
✓ 24	8	7	9	8	1
✓ 25	8	6	1	0	0
26	0	8	1	4	
27	0	4	2	3	
28	2	6	3	5	
29	9	4	4	3	
✓ 30	5	5	7	6	1

One teaching method was a typewritten illustrated manual (the complete manual is reproduced in Appendix G). The manual was developed after a complete task analysis and logic diagraming of the optimum strategy. The manual was organized according to the task logic flow diagram and emphasized the successive decision points and contingencies affecting bookkeeping procedures and test number selection.

The other teaching program consisted of a hierarchical series of logic diagrams. Because it was felt that most subjects would not be familiar with the symbology used in the diagrams, a set of preliminary instructions were prepared which explained the symbology and demonstrated its use by describing a familiar task (dialing a telephone). The diagrams for the numbers game are shown in Figures 4, 5, 6, 7, and 8. The diagrams are arranged in three levels, the highest level being the over-all task description. The level 2 diagrams provide details of elements of the over-all task description, and the level 3 diagrams show those of level 2. Each sub-level diagram was color-coded to aid in referencing with the higher level element it explained.

4. Procedures

Subjects were seated at a desk on which were placed the instructional materials, 3 x 5 cards, and bookkeeping forms. To the right of the subject was an opaque screen which concealed the experimenter. In the center of the screen was a narrow slot through which the subjects passed cards containing test numbers, and through which the experimenter passed scores for these numbers.

FIGURE 4. OVERALL TASK DIAGRAM FOR NUMBERS GAME USING BOOKKEEPING AIDS

OVERALL TASK DESCRIPTION

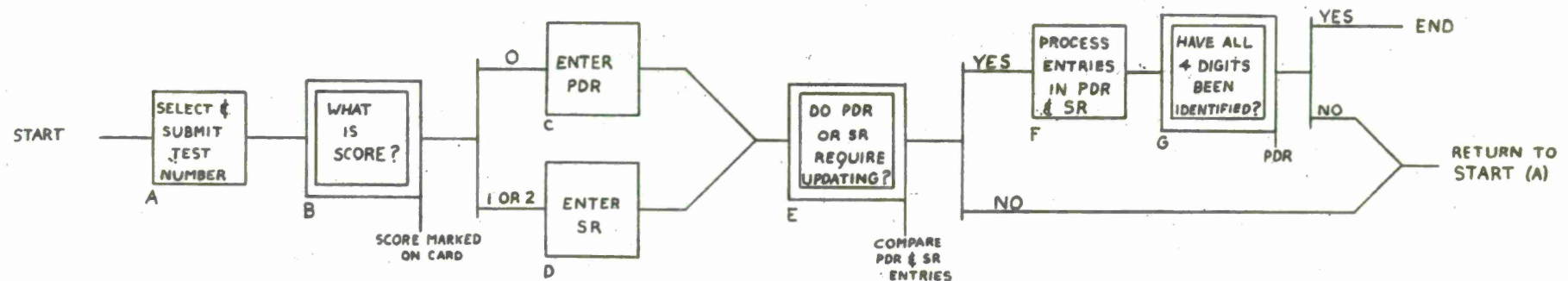


FIGURE 5. LEVEL 2 DIAGRAM

A. SELECT & SUBMIT TEST NUMBER

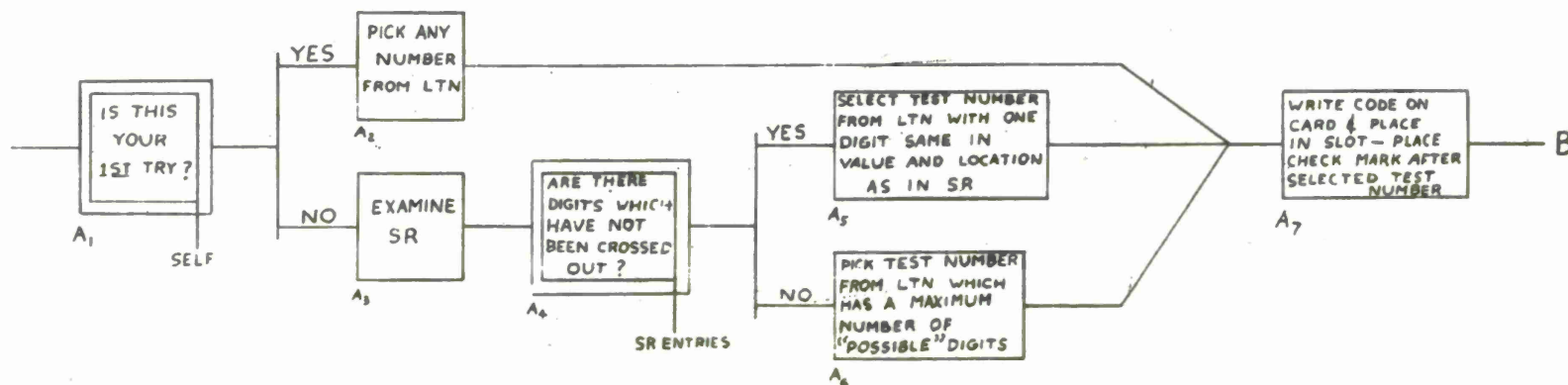
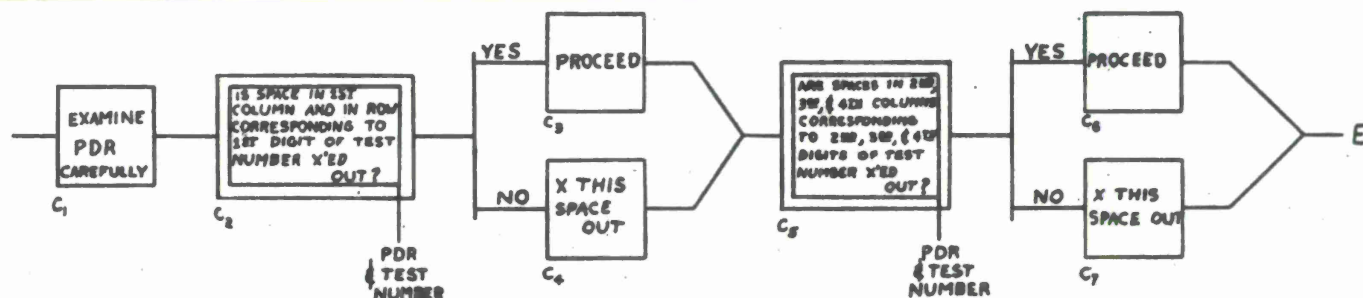
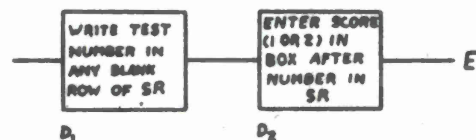


FIGURE 6 LEVEL 2 DIAGRAMS

C. ENTER ZERO SCORE IN PDR



D. ENTER SCORE OF 1 OR 2 IN SR



E. DETERMINE IF PDR OR SR REQUIRE UPDATING

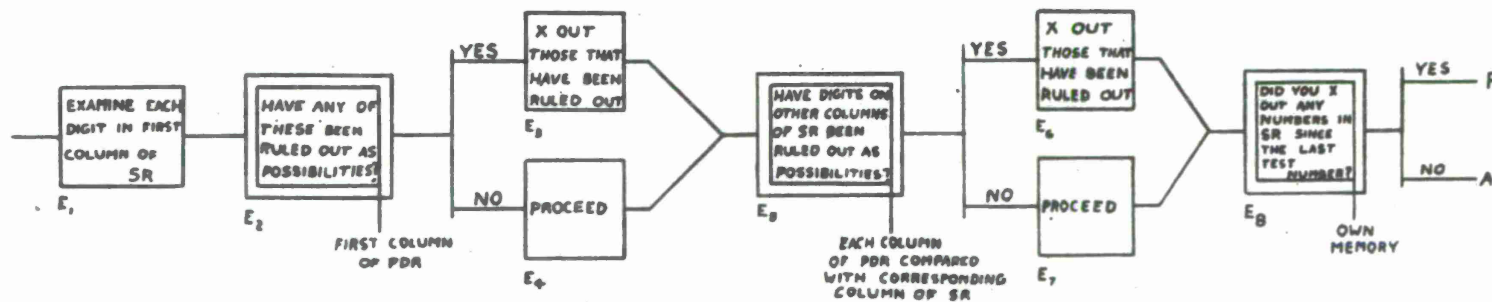


FIGURE 7. LEVEL 2 DIAGRAM

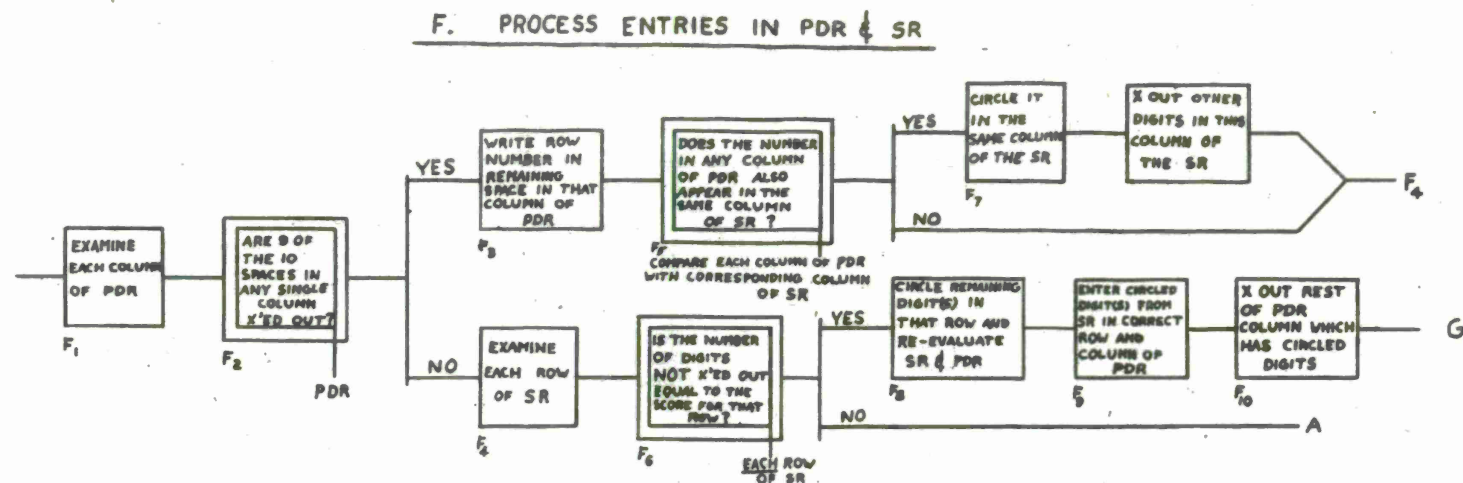
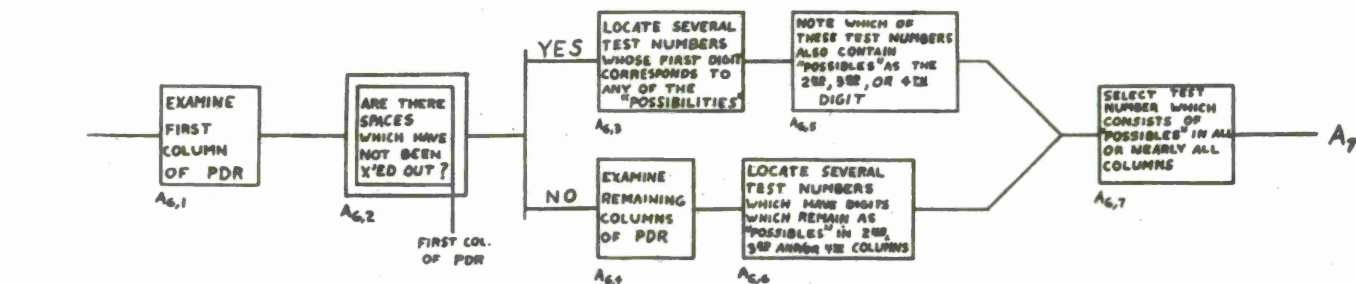
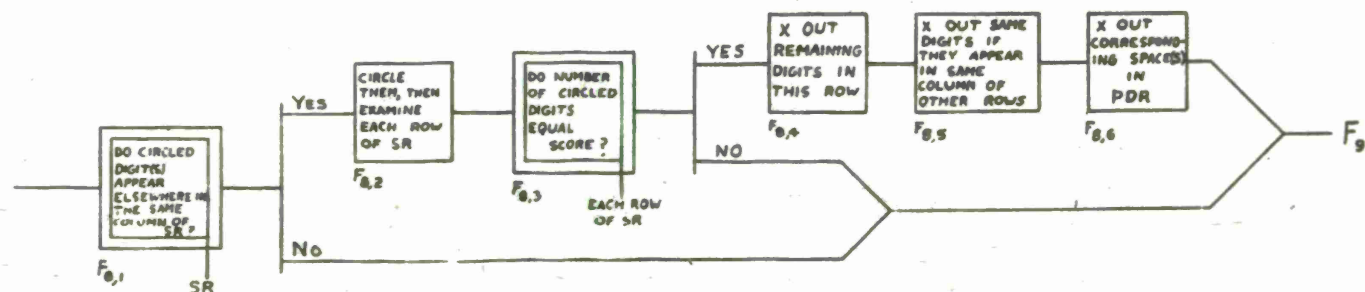


FIGURE 8. LEVEL 3 DIAGRAMS

A₆ PICK TEST NUMBER WITH A MAXIMUM NUMBER OF "POSSIBLE" DIGITS



F₈ RE-EVALUATE SR & PDR



Subjects were instructed to study the instruction manual, or the logic diagrams, and to begin the game whenever they felt that they understood the procedures. Instruction time commenced when the subject began to read the instructions and finished when he selected a test number, wrote it on a 3 x 5 card, and passed it through the slot in the screen. Each time a test number was submitted, the experimenter scored it, displayed the score to the subject, then recorded the time, number, and score. The game continued until the subject wrote the four digits of the "unknown" on a card and passed it through the slot. If he was correct, the time was recorded and the game ended. If he was wrong, the experimenter wrote "no" on the card, displayed it to the subject, and the game continued. There was no penalty, other than the time involved, for an incorrect guess.

Each subject played six games, with a five minute rest break between the third and fourth games. The six unknown numbers were the same for all subjects. If after working at least 35 minutes and 25 queries on any game the subject had not completed the unknown four digits, the game was discontinued and a new one started.

After all games were completed, the sequence of queries was reconstructed by the experimenter, analyzed, and evaluated. Each test number selected was categorized according to the potential new information which could be obtained if the subject followed an optimal strategy, and if he rigorously evaluated each successive score. The categories were: (1) maximally useful query, (2) query with some value, but more appropriate ones could have been used, and (3) zero value, test number which could not provide any information not deducible from previous queries.

For each game the total time, total number of queries, and total number of queries in each category represented the performance measures.

C. Results

Two subjects, one in each instruction group, were unsuccessful on one of the six trials. Both of these subjects completed the other five trails and their performance measures were included in the data analysis computations. Individual measures for each subject are reported in Appendix H. Because of the two incomplete trials, no mean scores could be computed. However, unusually large scores were occasionally observed for subjects on one trial and not on others, and these scores would have had a large influence on the mean. Median scores were used for comparison purposes to avoid undue emphasis on extreme values and permit inclusion of incomplete trial data. Median scores for all performance measures are listed in Table 4. Paired medians were statistically compared between the two groups by the Mann-Whitney U test (6). Median total number of queries were consistently less for the group using the logic flow diagrams (P less than 0.01), but none of the other comparisons showed statistically significant differences.

Median training time with the instruction manual was 9.3 minutes and with the logic diagrams was 14.5 minutes.

D. Discussion

Observation of performance indicated that those subjects who used the logic diagrams generally worked slowly and more carefully than did the subjects who read the instruction manual. Bookkeeping sheets were exam-

Table 4

Median Performance Data for
a Querying-Reasoning Task

		<u>Task</u>					
		<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>
A. Instruction Manual Group (n = 6)							
1.	Total time	18.2	12.2	12.0	10.0	9.0	10.4
2.	Number of queries*	15.5	15.5	16.0	14.3	13.5	14.5
	a) high value	9.0	11.5	9.0	11.5	9.0	11.5
	b) low value	3.0	1.0	2.0	3.0	2.5	1.0
	c) no value	3.0	2.5	3.5	1.0	1.5	1.0
B. Logic Diagram Group (n = 6)							
1.	Total time	17.5	9.0	14.4	17.6	10.7	11.2
2.	Number of queries*	14.5	12.0	14.0	12.5	12.5	13.0
	a) high value	10.5	9.0	10.5	10.5	10.0	11.5
	b) low value	3.0	2.0	1.0	2.0	2.0	2.0
	c) no value	1.0	0.0	1.5	2.0	0.0	0.5

*Since all values reported are medians, the sum of the medians in the three categories will not necessarily equal the median total number of queries.

ined for clues as to how well the subject followed the instructions, and as to the nature of any errors which he made. Aberrant performance was generally due either to errors in the mechanics of bookkeeping or to failure to use the bookkeeping aids. It was not possible to generalize whether the techniques for use of the bookkeeping aids differed between the two groups, or whether the method of instruction differentially affected accuracy and completeness of application.

The results of this experiment may be compared with those of a previous experiment in which a variety of training techniques were compared (1). Median number of queries for the logic diagram group compares favorably with that achieved by any of the other previously studied groups, except when the bookkeeping function was performed for the subjects by a simulated computing system and displayed after each query.

Although the observed median training time with the logic diagrams was longer than with the instruction manual, two subjects completed study of the diagrams in less time than did the fastest subjects with the manual. Individual training times with the diagrams ranged from 4 to 53 minutes but only from 8 to 13 minutes with the instruction manual. It is hypothesized that those individuals who required little time to study the logic flow diagrams were familiar with flow diagrams in other fields, and that if these diagrams were used more frequently for teaching purposes, individual differences in study time would be greatly reduced.

V. APPLICATION CONSIDERATIONS

The preceding three sections of this report describe experiments which demonstrated the feasibility of using three novel teaching programs to teach three different tasks. Although any one of the three teaching program concepts might be applied to all three of the tasks, the ease and cost of implementation would differ widely.

The first experiment illustrated principles which should have wide application in terms of ordering instructional programs. Ordering according to the discovery principle need not be restricted to instruction in use of multiple controls. Programs for use of any man-machine system can exploit this principle. However, the economics of providing processing of active responses by the trainee may restrict strict adherence to an automated phylogenic-type program to use with sophisticated computer-based systems. Further study is needed to determine to what extent the discovery principle should be used to guide human instructors, to upgrade conventional automated instruction programs, or even for ordering training manual material.

The second experiment demonstrated that inexpensive presentation equipment can be effectively used to supplement operational equipment in an on-the-job teaching program. The experiment also illustrated the use of logic flow diagrams as a portion of a teaching program. For use with computer-based systems, access to the computer program would permit inclusion of a branching program based on response evaluation and of

primary reinforcement of correct responses. However, the principle objective of the present experiment was to show how an automated instruction program can be implemented without modifying operational equipment, and in which the operational equipment serves as an integral part of the instructional program. Since the instructions, cues, and diagrams are projected directly onto the console, transfer from one "picture" to another (as, for example, with a book) is minimized. Frames can be of variable size, active responses required of the trainee, and response evaluation included in the slide/tape program. Use of a projection screen along the periphery may suffice when teaching control sequences, although such an arrangement would be little different than use of an illustrated book. To permit the trainee to advance at his own pace, a remote switch for advancing the slide sequence and for playing the tape (a standard increment) should be provided. For rapid programing, frame and lecture material may duplicate the lecture-demonstration presentation of a skilled instructor. Larger information content frames in random access slide/tape units may also be utilized for review purposes or as performance aids during routine operation of the equipment. An occasional user of an information system console might consult diagrams or contextual information projected onto the console rather than referring to an instruction manual.

The use of logic flow diagrams as instructional material was demonstrated in both the second and third experiments. The benefits which may be expected to accrue from use of these diagrams will depend largely on

the abilities and past experiences of the trainees. If the diagrams gain wide acceptance, their effectiveness and efficiency as a language will increase. The potential applications for diagrammatic representation of task characteristics are believed to be widespread.

VI. CONCLUSIONS AND RECOMMENDATIONS

The experimental results reported in this document confirm and expand previously reported preliminary studies and hypotheses. Specific conclusions derived from the results, and recommendations for application or further study are as follows:

1. A phylogenic presentation of control function ordered according to the discovery principle is an effective format for instruction. Implementation problems (primarily machine recognition of language) will restrict applications unless conventional means of guiding and evaluating the overt response can be used. It is recommended that the discovery principle be further studied for determining its potential as a means of ordering written or verbal (instruction manuals or lectures) instructional material for future computer-based information systems. Consideration should be given to ordering self-instruction programs according to the discovery principle.
2. Graphical logic flow diagrams can be used independently or with other material in instructional programs. Although trainees unfamiliar with such diagrams may require additional instruction in symbology, repeated exposure to this specialized language will increase speed and comprehension of reading. It is recommended that graphical logic flow diagrams be tried as teaching aids in an actual Air Force training situation.
3. Slide/tape instruction programs can be used to provide automated instruction or practice for console operators seated at operational equipment. Since no equipment modifications are required, it is recommended

that such a program be developed and used as a training device with an existing operational system.

VII. REFERENCES

1. Sheridan, T. B. and Mayer, S. R. Design and Use of Information Systems for Automated on-the-job Training: Vol. I. Conceptual and Experimental Approaches, ESD-TDR-64-234, Decision Sciences Laboratory, Electronic Systems Division, L. G. Hanscom Field, Massachusetts, 1963.
2. Sheridan, T. B., Duggar, B. C., and Mayer, S. R. Design and Use of Information Systems for Automated on-the-job Training: Vol. II. Design of Self-Instructional Features, ESD-TDR-64-234, Decision Sciences Laboratory, Electronic Systems Division, L. G. Hanscom Field, Massachusetts, 1964.
3. Mosel, J. N. "The Learning Process", J. Med. Educ., 39, 485-496, 1964.
4. (Symbology report to be issued concurrently, reference data to be supplied.)
5. Duncan, D. B. "Multiple Range and Multiple F Tests", Biometrics, 11, 1-42, 1955.
6. Siegel, S. Nonparametric Statistics, McGraw-Hill, New York, 1956.
7. Carter, L. F. "Automated Instruction", Amer. Psychologist, 16, 705-710, 1961.
8. Strollo, T. R. A Generalized Teaching Machine Decision Structure with Application to Speed Reading, ESD-TDR-64-523, Decision Sciences Laboratory, Electronic Systems Division, L. G. Hanscom Field, Massachusetts, 1964.
9. "Design Evolution Gains Maximum Utility", Aviat. Week and Space Tech., 81, 106-112, September 7, 1964.
10. Lee, R. and Anderson, N. S. Application of Human Factors in Maintenance of Electronic Systems, paper presented at the 4th National Symposium on Human Factors in Electronics, Washington, D. C., May, 1963.

APPENDIX A

Instruction Manual for Operation of the Lissajous Figures Control Console

The instruction manual was modeled after an Operator's Handbook for a laboratory oscilloscope. The order in which control functions were introduced initially followed that used in the phylogenic program. However, pilot experiments revealed that subjects experienced the most difficulty with the elliptical control (knob #1) and that this difficulty could be reduced by introducing that control last. The manual appears in the following paragraphs.

Introduction

This manual describes functions which are used to control a variety of figures on a display screen. Use this manual in the following sequence:

1. read descriptions for each control,
2. try to manipulate these controls so that you are familiar with their functions,
3. do the criterion problems as they are suggested.

You will have about one and one-half hours to read this manual. After the first hour or at a convenient point in your reading, you may take a 10-minute rest.

When you finish reading the entire manual and do the criterion slides, you will get another 10-minute rest. After this rest period, you will be given a test which will consist of slides having single and double figures.

The Console

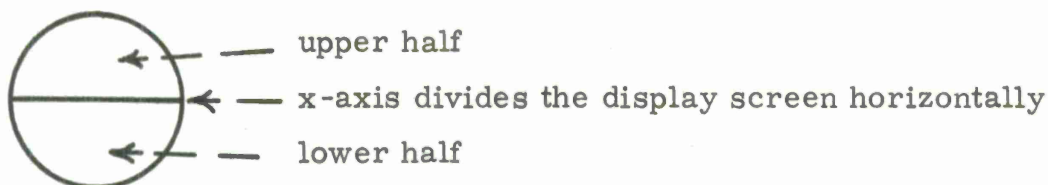
The console contains knobs and switches which control figures on the display screen. These controls are divided into two groups, each consisting of nine knobs and three switches. The first group (the black knobs and the switches below them) is located on the left-hand side of the console; the second group (the white knobs and the switches below them) is located on the right-hand side of the console. Each knob and switch is numbered for later identification and reference.

Diagrams, which graphically indicate the functions of the particular control, are located next to each knob in group one (left-hand side). The functions of the knobs and switches on the right-hand side are identical to those of corresponding knobs in the first group.

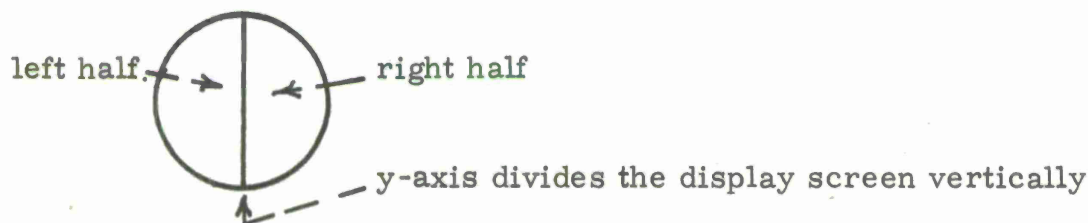
To set up the console initially, switches 10 and 12 should be down, and switch 11 should be up (left-hand side).

The Display

The display screen may be divided into four quadrants by horizontal (x-axis) and vertical (y-axis) lines crossing each other at the center. The x-axis divides the display screen into upper and lower halves.



The y-axis divides the display screen into left and right halves.



The x-axis also represents the horizontal line, while the y-axis represents the vertical line--these designations are used interchangeably in the descriptions that follow.

Functions of the Controls

Knob #7 - x-axis or horizontal position control

The x-axis divides the display screen into upper and lower halves. Knob #7 controls the position of any figure along the x-axis. Turning the knob clockwise, the figure moves to the right; turning the knob counter-clockwise, the figure moves to the left.

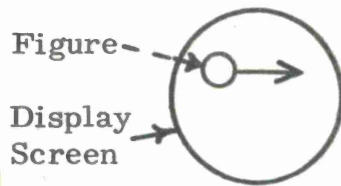


Figure moves
from left to right

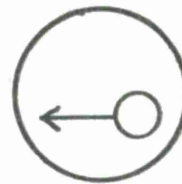


Figure moves
from right to left



Knob #7 turns
clockwise



Knob #7 turns
counterclockwise

Knob #6 - y-axis or vertical position control

The y-axis divides the display screen into right and left halves. Knob #6 controls the position of any figure along the y-axis. Turning the knob clockwise, the figure moves from bottom to top of the display screen; turning the knob counterclockwise, the figure moves from top to bottom.

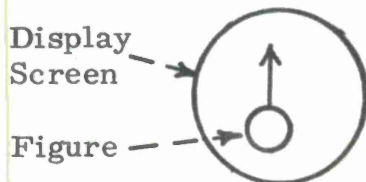


Figure moves
from bottom
to top

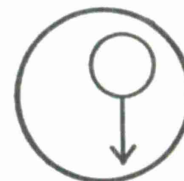


Figure moves
from top to
bottom



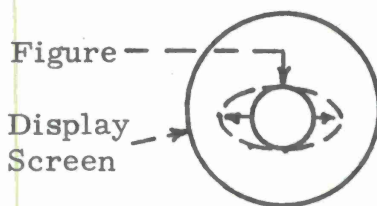
Knob #6 turns
clockwise



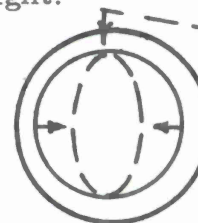
Knob #6 turns
counterclockwise

Knob #5 - amplitude along the x-axis or the horizontal line

Amplitude is defined as the size or dimension along a given axis. Knob #5 controls the largeness or smallness of the figure only along the x-axis. For example, turning the knob clockwise changes the circle into an ellipse without changing the vertical height.



Circle is ex-
panded horizon-
tally to form an
ellipse



Circle is con-
tracted horizon-
tally to form an
ellipse



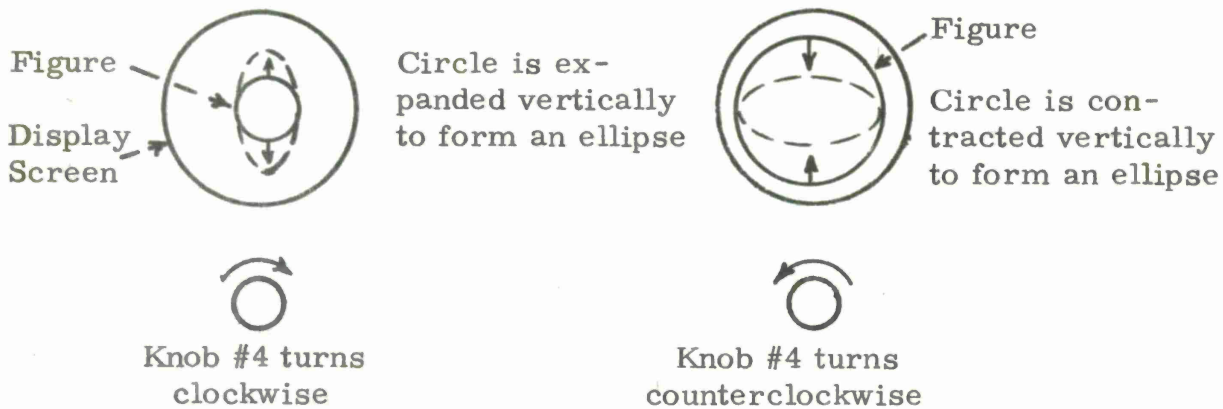
Knob #5 turns
clockwise



Knob #5 turns
counterclockwise

Knob #4 - amplitude along the y-axis or the vertical line.

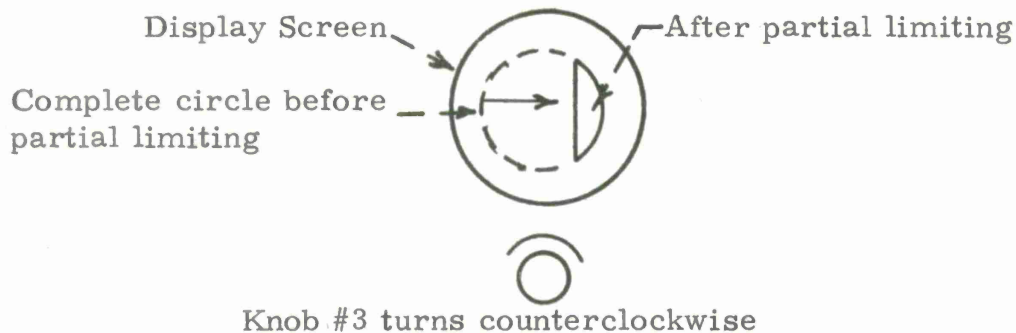
Whereas knob #5 controls largeness or smallness of a figure along the x-axis, knob #4 controls largeness or smallness of a figure along the y-axis.



The function of knob #4 is exactly the same as that of knob #5, except that knob #4 controls the amplitude along the y-axis without affecting any other dimensions.

Knob #3 - x-axis or horizontal partial limiting

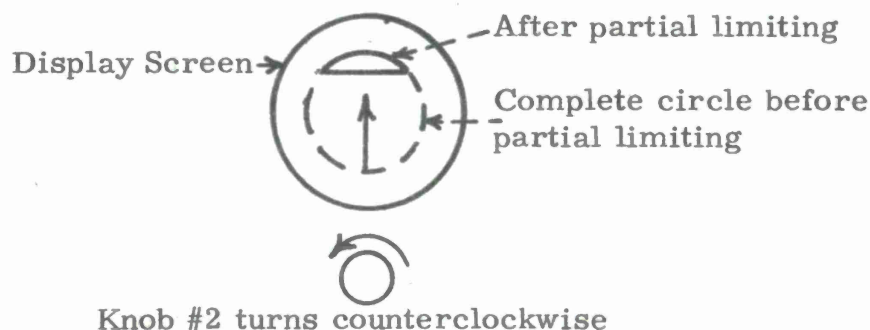
Partial limiting is a change in some part of the figure without changing the remaining characteristics of the figure. Knob #3 controls partial limiting along the x-axis. For example:



Turning knob #3 counterclockwise, the circle changes to a semicircle with a flat side on the left. Turning knob #3 still further clockwise, the semicircle changes into a solid vertical line whose height is equal to the diameter of the circle. Partial limiting function works on any figure regardless of its position in the display. The main characteristic of the partial limiting function is a vertical line which represents the reduced part of the figure.

Knob #2 - y-axis or vertical partial limiting

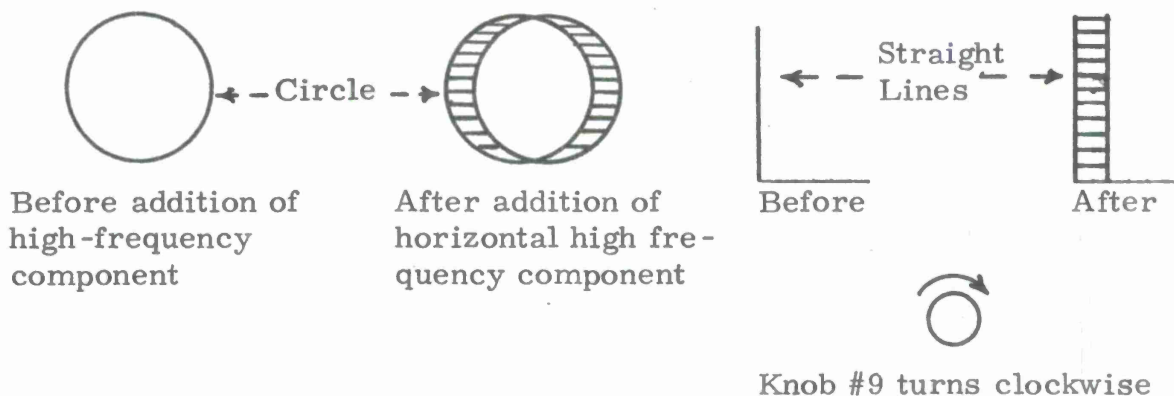
Knob #2 controls partial limiting along the y-axis.



The diagram illustrates the effects of partial limiting on the circle. The remaining characteristics of y-axis partial limiting are the same as those of x-axis partial limiting.

Knob #9 - x-axis or horizontal line width (high frequency)

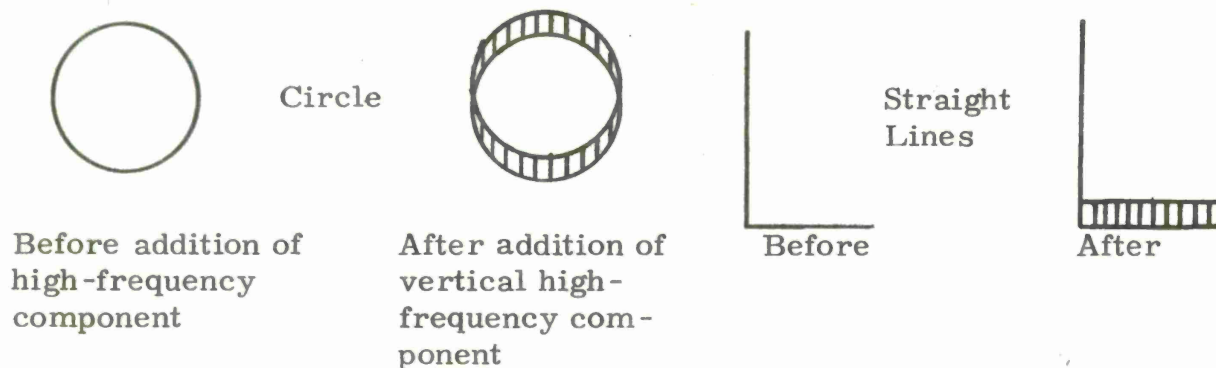
To produce heavy or tube-like figures which have a three-dimensional appearance, a high-frequency component is used. Knob #9 controls the high-frequency component along the x-axis and will expand lines of any figure in this direction.



Knob #9 expands the lines of any figure along the x-axis by adding a horizontal high-frequency component.

Knob #8 - y-axis or vertical line width (high frequency)

Knob #8 controls the high-frequency component along the y-axis, and will expand lines of any figure vertically.

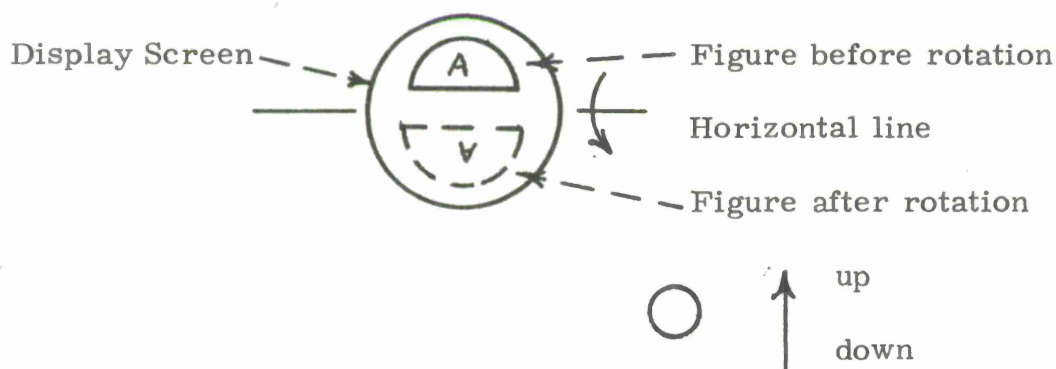


Knob #8 turns clockwise

The high-frequency component can be used with any figure appearing on the display screen, but knob #8 controls it only along the y-axis.

Switch #10 - x-axis or horizontal mirror-image

The console is not designed for continuous rotation of the figures (such as triangles being rotated clockwise). Instead, the limited rotation is provided by rotating the figure in discreet steps about x- and y-axes. Switch #10 is used to rotate the figure about x-axis; i. e., rotate the figure around the horizontal line.

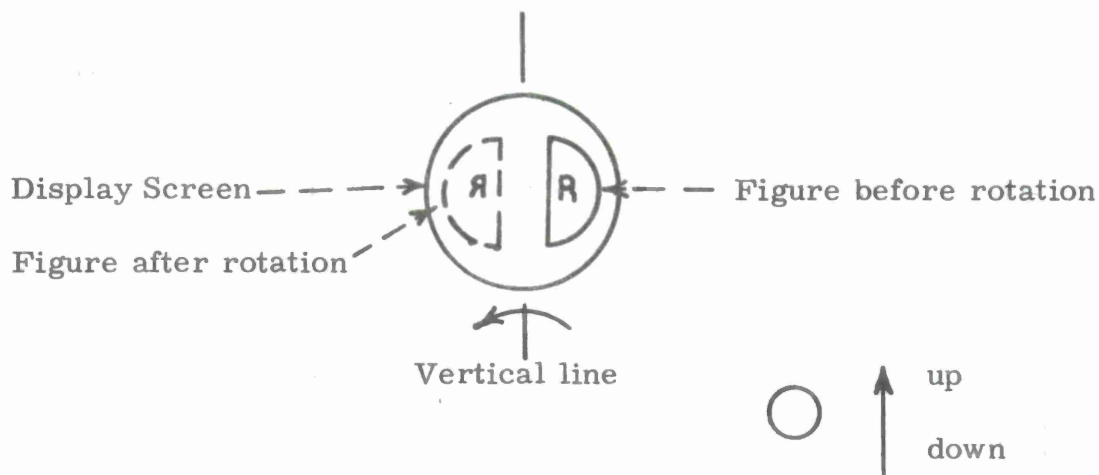


Raising switch #10 flips from upward to downward position.

Switch #10 can be used to obtain mirror -images of all figures, but the end result is best seen with noncircle figures.

Switch #12 - y-axis or vertical mirror-image

The function of switch #12 is to rotate any figure about y-axis or vertical line.

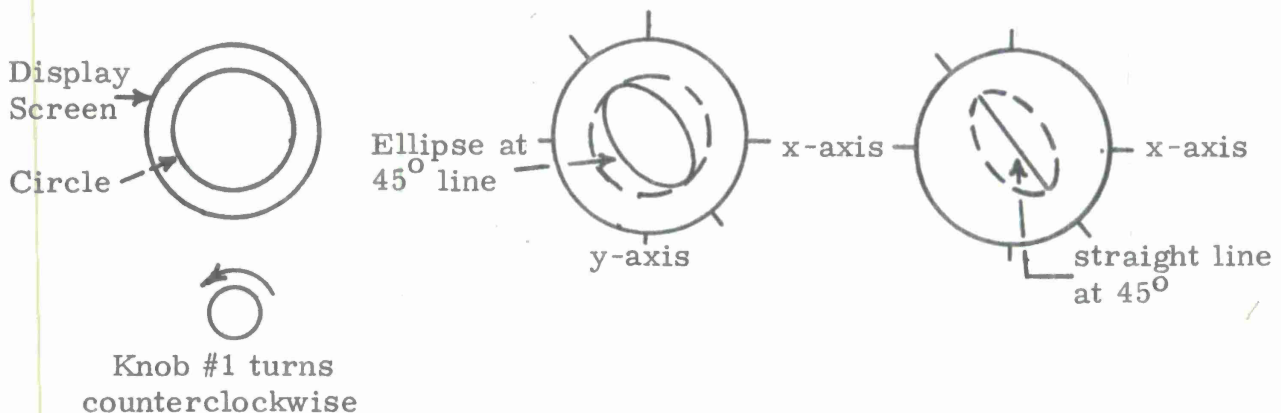


Raising switch #12 flips from
right to left

Again, the best figures for vertical mirror-image are noncircles.

Knob #1 - common to both x- and y-axes

Knob #1 is used to produce elliptical figures or lines which are inclined at 45° (this angle will vary if the vertical and horizontal gains, knobs #4 and #5, are unequally set). Knob #1 can be used with most figures, but its effects will be most noticeable on circles, semicircles, and ellipses. Knob #1 will have no effect on figures which have partial limiting functions increased to their maximum.



Turning knob #1 changes a circle into an ellipse which is inclined at 45° . This angle is obtained if both vertical and horizontal gains are set equally. Turning knob #1 still further, ellipse is reduced into a straight line, which is inclined at 45° .

Available Figures

A great variety of figures can be reproduced on the display by manipulating the controls individually or in various combinations. All figures may be

regarded as distortions of a circle, produced through changes in amplification, roundness, limiting, addition of high-frequency components to broaden the lines, or rotation. Starting with the basic circle, it should be possible to analyze which controls will be required, and the order in which they should be adjusted.

Presentation of Criterion Slides

Translucent slides illustrating the figures which you must reproduce can be inserted in front of the display screen. You will be able to see simultaneously the figure on the display screen and the figure on the translucent slide. Match reasonably close the figure on the display screen in size, shape, and position to the slide figure. To insert the slide, orient it so that the number is inverted and appears in the upper left-hand corner, and the cross-hatched thumb mark appears in the lower left-hand corner facing you. Insert slides into the receptacle which is just below the display screen. There is a catch on the left of the receptacle to help you in the positioning of the slide. Check how the slide figure differs from that already on the display screen. Decide which controls will be used, and the order in which they should be manipulated. Then change the figure on the display screen to match that on the slide. The order of slides is from one to sixty for single figures (using left-hand group of console controls), and 60 to 80 for double figures.

There is a listing of controls for each slide on 3 x 5 inch cards. The order of control manipulations is suggestive in nature and should be used as a guide. The list of controls for slide #1 is applicable only if the figure on the display screen is a circle. The list of controls for slide #2 is applicable only if the figure on the display screen is similar to that on the previous slide. Similar assumptions are true for the remaining slides.

Slide #1 - Controls: #7 Adjust horizontal position

Slide #2 - Controls: #6 Adjust vertical position

Slide #3 - Controls: #6 Adjust vertical position
#7 Adjust horizontal position

Slide #4 - Controls: #1 Make an ellipse
#6 Adjust vertical position
#7 Adjust horizontal position

Slide #5 - Controls: #1 Make a single line
#6 Adjust vertical position
#7 Adjust horizontal position

Slide #6 - Controls: #1 Make a circle
#6 Adjust vertical position

Slide #7 - Controls: #5 Increase horizontal gain

Slide #8 - Controls: #4 Increase vertical gain
#6 Adjust vertical position
#7 Adjust horizontal position

Slide #9 - Controls: #4 Reduce vertical gain
#5 Reduce horizontal gain
#7 Adjust horizontal position

Slide #10 - Controls: #5 Reduce horizontal gain
#7 Adjust horizontal position

Slide #11 - Controls: #5 Increase horizontal gain
#6 Adjust vertical gain
#4 Reduce vertical gain

Slide #12 - Controls: #7 Adjust horizontal position
#6 Adjust vertical position
#4 Increase vertical gain

Slide #13 - Controls: #1 Make an ellipse

Slide #14 - Controls: #1 Make a circle
#5 Reduce horizontal gain

Slide #15 - Controls: #1 Make an ellipse
#4 Reduce vertical gain

Slide #16 - Controls: #1 Make a circle
#4 Increase vertical gain
#5 Increase horizontal gain

Slide #17 - Controls: #1 Make a single line
#4 Reduce vertical gain
#6 Adjust vertical position

Slide #18 - Controls: #5 Reduce horizontal gain
#7 Adjust horizontal position
#6 Adjust vertical position

Slide #19 - Controls: #1 Make a circle
#4 Increase vertical gain
#5 Increase horizontal gain
#7 Adjust horizontal position

Slide #20 - Controls: #6 Adjust vertical position
#7 Adjust horizontal position

Slide #21 - Controls: #3 Increase horizontal partial limiting
#7 Adjust horizontal position
#6 Adjust vertical position

Slide #22 - Controls: #2 Increase vertical partial limiting

Slide #23 - Controls: #2 Reduce vertical partial limiting
#3 Reduce horizontal partial limiting

Slide #24 - Controls: #4 Reduce vertical gain
#3 Increase horizontal partial limiting

Slide #25 - Controls: #3 Reduce horizontal partial limiting
#5 Reduce horizontal gain
#2 Increase vertical partial limiting

Slide #26 - Controls: #2 Reduce vertical partial limiting
#4 Increase vertical gain
#5 Increase horizontal gain
#6 Adjust vertical position
#7 Adjust horizontal position

Slide #27 - Controls: #1 Make an ellipse

Slide #28 - Controls: #1 Make a larger ellipse
#3 Increase horizontal partial limiting

Slide #29 - Controls: #2 Increase vertical partial limiting

Slide #30 - Controls: #2 Reduce vertical partial limiting
#3 Reduce horizontal partial limiting

Slide #31 - Controls: #1 Make a single line
#3 Increase horizontal partial limiting
#4 Increase vertical gain

Slide #32 - Controls: #2 Increase vertical partial limiting
#5 Increase horizontal gain
#7 Adjust horizontal position
#1 Make an ellipse

- Slide #33 - Controls: #2 Reduce vertical partial limiting
#3 Reduce horizontal partial limiting
#1 Make a circle
#4 Reduce vertical gain
#5 Reduce horizontal gain
- Slide #34 - Controls: #4 Reduce vertical gain
#5 Reduce horizontal gain
#7 Adjust horizontal position
- Slide #35 - Controls: #9 Increase horizontal high-frequency component
- Slide #36 - Controls: #8 Increase vertical high-frequency component
- Slide #37 - Controls: #8 Reduce vertical high-frequency component
#9 Reduce horizontal high-frequency component
- Slide #38 - Controls: #3 Increase horizontal partial limiting
#9 Increase horizontal high-frequency component
- Slide #39 - Controls: #2 Increase vertical partial limiting
#9 Reduce horizontal high-frequency component
#8 Increase vertical high-frequency component
- Slide #40 - Controls: #8 Reduce vertical high-frequency component
#2 Reduce vertical partial limiting
#3 Reduce horizontal partial limiting
#7 Adjust horizontal position
- Slide #41 - Controls: #1 Make an ellipse
#9 Increase horizontal high-frequency component
#6 Adjust vertical position
- Slide #42 - Controls: #1 Make a circle
#8 Increase vertical high-frequency component
#6 Adjust vertical position
- Slide #43 - Controls: #8 Reduce vertical high-frequency component
#9 Reduce horizontal high-frequency component
#1 Make an ellipse
- Slide #44 - Controls: #1 Make a solid line
#2 Increase vertical partial limiting
#9 Increase horizontal high-frequency component

Slide #45 - Controls: #3 Increase horizontal partial limiting
#2 Make an ellipse
#8 Increase vertical high-frequency component

Slide #46 - Controls: #8 Reduce vertical high-frequency component
#9 Reduce horizontal high-frequency component

Slide #47 - Controls: #10 Mirror-image about horizontal axis

Slide #48 - Controls: #12 Mirror-image about vertical axis

Slide #49 - Controls: #10 Mirror-image about horizontal axis
#12 Mirror-image about vertical axis

Slide #50 - Controls: #10 Mirror-image about horizontal axis
#9 Increase horizontal high-frequency component

Slide #51 - Controls: #12 Mirror-image about vertical axis
#10 Mirror-image about horizontal axis
#8 Increase vertical high-frequency component
#6 Adjust vertical position
#7 Adjust horizontal position

Slide #52 - Controls: #8 Reduce vertical high-frequency component
#9 Reduce horizontal high-frequency component
#12 Mirror-image about vertical axis

Slide #53 - Controls: #10 Mirror-image about horizontal axis
#1 Adjust ellipse

Slide #54 - Controls: #12 Mirror-image about vertical axis
#1 Adjust ellipse
#6 Adjust vertical position
#7 Adjust horizontal position

Slide #55 - Controls: #10 Mirror-image about horizontal axis
#12 Mirror-image about vertical axis
#1 Adjust ellipse

Slide #56 - Controls: #1 Make a single line
#10 Mirror-image about horizontal axis
#8 Increase vertical high-frequency component

Slide #57 - Controls: #1 Make an ellipse
#12 Mirror-image about vertical axis
#9 Increase horizontal high-frequency component

Slide #58 - Controls: #1 Make a single line
#10 Mirror-image about horizontal axis
#12 Mirror-image about vertical axis

Slide #59 - Controls: #8 Reduce vertical high-frequency component
#9 Reduce horizontal high-frequency component
#1 Make an ellipse

Slide #60 - Controls: #2 Reduce vertical partial limiting
#3 Reduce horizontal partial limiting
#1 Make a circle
#4 Reduce vertical gain
#5 Reduce horizontal gain

Double Figures

Two figures can be simultaneously displayed by using both the left- and the right-hand groups of controls. The knobs and switches in the right-hand group are numbered to correspond to those in the left-hand group. It is advisable to work on reproducing one figure at a time, then switching to the other figure when the first is completed. When switch #11 is in the up (ON) position, the figure produced by the left-hand group of controls will appear on the display screen. When switch #13 is in the up (ON) position, the figure produced by the right-hand group of controls will appear on the display screen. If both switches are in the ON position, both figures will appear simultaneously on the display screen.

Presentation of Criterion Slides (Double Figures)

The order of slides for double figures (both groups of controls are needed) is from 61 to 80.

The listing of controls and their order are suggestive in nature. It is assumed that Figure A is controlled by the left side of controls, and Figure B by the right side of controls. Moreover, it is assumed that the figures on the display screen are similar to those on the preceding slide.

Slide #61 - Figure A. Controls: #6 Adjust vertical position
#7 Adjust horizontal position
Figure B. Controls: #4 Adjust vertical gain
#5 Adjust horizontal gain
#6 Adjust vertical position
#7 Adjust horizontal position

Slide #62 - Figure A. Controls: #2 Increase vertical partial limiting
 #6 Adjust vertical position
 Figure B. Controls: #4 Increase vertical gain
 #5 Reduce horizontal gain

Slide #63 - Figure A. Controls: #10 Mirror-image about horizontal axis
 #6 Adjust vertical position
 Figure B. Controls: #5 Increase horizontal gain
 #2 Increase vertical partial limiting
 #3 Increase horizontal partial limiting
 #6 Adjust vertical position
 #7 Adjust horizontal position

Slide #64 - Figure A. Controls: #3 Increase horizontal partial limiting
 #1 Make a single line
 #12 Mirror-image about vertical axis
 #10 Mirror-image about horizontal axis
 #6 Adjust vertical position
 #7 Adjust horizontal position
 Figure B. Controls: #10 Mirror-image about horizontal axis
 #6 Adjust vertical position
 #7 Adjust horizontal position

Slide #65 - Figure A. Controls: #1 Make an ellipse
 #9 Increase horizontal high-frequency component
 Figure B. Controls: #7 Adjust horizontal position
 #9 Increase horizontal high frequency component

Slide #66 - Figure A. Controls: #1 Make a solid line
 #8 Increase vertical high-frequency component
 Figure B. Controls: #7 Adjust horizontal position
 #8 Increase vertical high-frequency component

Slide #67 - Figure A. Controls: #1 Make an ellipse
 #12 Mirror-image about vertical axis
 Figure B. Controls: #12 Mirror-image about vertical axis
 #7 Adjust horizontal position

Slide #68 - Figure A. Controls: #8 Reduce vertical high-frequency component
 #9 Reduce horizontal high-frequency component
 Figure B. Controls: #8 Reduce vertical high-frequency component
 Figure B. Controls: #8 Reduce horizontal high-frequency component

- Slide #69 - Figure A. Controls: #1 Make a single line
 Figure B. Controls: #1 Make a single line
 #8 Increase vertical high frequency component
 #9 Increase horizontal high-frequency component
- Slide #70 - Figure A. Controls: #2 Reduce vertical partial limiting
 Figure B. Controls: #2 Reduce vertical partial limiting
 #3 Reduce horizontal partial limiting
 #12 Mirror-image about vertical axis
- Slide #71 - Figure A. Controls: #7 Adjust horizontal position
 Figure B. Controls: #8 Reduce vertical high-frequency component
 #9 Reduce horizontal high-frequency component
 #3 Increase horizontal partial limiting
 #10 Mirror-image about horizontal axis
 #12 Mirror-image about vertical axis
- Slide #72 - Figure A. Controls: #10 Mirror-image about horizontal axis
 #6 Adjust vertical position
 #7 Adjust horizontal position
 Figure B. Controls: #7 Adjust horizontal position
- Slide #73 - Figure A. Controls: #3 Reduce horizontal partial limiting
 #2 Increase vertical partial limiting
 #8 Increase vertical high-frequency component
 #7 Adjust horizontal position
 Figure B. Controls: #3 Increase horizontal partial limiting
 #4 Increase vertical gain
 #6 Adjust vertical position
 #9 Increase horizontal high-frequency component
- Slide #74 - Figure A. Controls: #6 Adjust vertical position
 Figure B. Controls: #3 Reduce horizontal partial limiting
 #2 Increase vertical partial limiting
 #8 Increase vertical high-frequency component
 #6 Adjust vertical position

- Slide #75 - Figure A. Controls: #9 Increase horizontal high-frequency component
Figure B. Controls: #2 Reduce vertical partial limiting
#3 Increase horizontal partial limiting
#4 Reduce vertical gain
#6 Adjust vertical position
- Slide #76 - Figure A. Controls: #2 Reduce vertical partial limiting
Figure B. Controls: #3 Reduce horizontal partial limiting
#12 Mirror-image about vertical axis
- Slide #77 - Figure A. Controls: #8 Reduce vertical high-frequency component
#9 Reduce horizontal high-frequency component
Figure B. Controls: #9 Reduce horizontal high-frequency component
- Slide #78 - Figure A. Controls: #6 Adjust vertical position
#7 Adjust horizontal position
Figure B. Controls: #8 Reduce vertical high-frequency component
#6 Adjust vertical position
#7 Adjust horizontal position
- Slide #79 - Figure A. Controls: #1 Make a circle
#6 Adjust vertical position
#7 Adjust horizontal position
#9 Increase horizontal frequency
Figure B. Controls: #6 Adjust vertical position
#7 Adjust horizontal position
- Slide #80 - Figure A. Controls: #9 Reduce horizontal high-frequency component
Figure B. Controls: #1 Make a circle
#4 Reduce vertical gain
#5 Reduce horizontal gain
#6 Adjust vertical position
#7 Adjust horizontal position

APPENDIX B

Instructions for the Phylogenic Teaching Program

The instructions were presented in two parts: the first described the task and procedures, and was given to the subject as soon as he was seated, the second part, (additional instructions) was given to the subject after he had completed all the single figure slides.

Instructions

Your task is to learn the functions which control the figure on the display screen.

In front of you is a console to control figures on the screen. The console consists of two panels of controls--the left panel and the right panel. You will use the left panel first. There are 12 numbered places for controls (9 knobs and 3 switches).

Learn to control the figures on the screen by changing them to match reasonably well the figures on the slides which will be inserted in front of the screen. You will have to decide how these figures differ from one another, and what control(s) you need to change the figures on the screen.

Initially the left panel will not have any controls. When you need a new control, tell me in your own words what such a control will do to the screen. If your requested control is actually needed to change the figure at that time, I will give it to you. A numbered knob or a switch will appear on the table to the right of the console. Take that numbered control and match it to the number on the panel. Before inserting the control into its proper place, remove the numbered label and place it on the upper part of the console. Under the numbered label is a graphical drawing which shows what the control does. You may not look under labels until you receive controls for those positions.

If your request for a control is untimely, or if you request a control to change too many features of the figure on the screen, or change it in an unacceptable manner, the request will not be granted. I will show you a comment to this effect.

When you have matched reasonably close the figure on the screen to that on the slide, press the button on the right side of the console.

If the match is close enough, you will see a green light (above the display screen) go on. Then, we will proceed to the next slide. If your match is not adequate, a red light will go on. Then you will have to readjust your controls so that both figures match reasonably well.

Additional Instructions

You learned to control single figures on the display screen. Now you will learn to control two figures on the screen.

The controls on the right hand side panel are identical in functions to those on the left hand side. Insert the white knobs and switches into the right hand side panel. Be certain that these white controls are matched by number and place to the controls on the left hand side.

It is advisable to work on one figure at a time. When you have a reasonably close matching of both single figures, turn on both panels to display both figures simultaneously.

APPENDIX C

Instructions for the Verbal Analysis Teaching Program

As with the phylogenic program, instructions were presented at the start, and then additional instructions were given after all the single figure slides had been completed.

Instructions

Your task is to learn to analyze the differences between two geometrical figures, and then specify how to change one of them so that they are identical. To accomplish these changes you will be restricted to eleven control "functions". Thus, your task is also to learn these functions.

For each problem there will be two geometrical figures, one on the display screen, and the other on a transparent slide which will be placed in front of the display screen. When the slide is first inserted, the two figures will not match. You will decide how these two figures differ from one another, and what "functions" you will need to change the figure on the display screen to match that on the slide (for example, if the two figures are geometrically the same, but that on the slide is above the other, you would wish to raise the display screen figure. Thus you would use a "vertical position" or y-axis function). You will not be told beforehand what the available "functions" are, but as you ask for needed functions your requests will be evaluated and if it is appropriate the figure will be altered and you will be instructed to remove the covering from one of the cards on the board in front of you. The function which you requested is described under this covering and may be requested on subsequent problems whenever you think it appropriate. If, however, the function which you initially request is not one of the eleven control functions you will receive a "comment". You may not look under the numbered cards on the board until you are told to do so.

When you are satisfied that the two figures correspond in size, shape, and position, say that you are "ready". If the match is satisfactory you will see a green light over the screen and you may go on to the next problem. If the match is not satisfactory the red light will come on and you will have to continue to improve the match.

Additional Instructions

You have learned to match single figures on the display screen. Now you will learn to match double figures.

Match one of the controlled figures at a time to one on the slide. Identify the figure you wish to control by referring to the right or left hand figure. When both figures match the two on the slide signal that you are "ready".

APPENDIX D

Individual Performance Measures for the Lissajous Figure Control Console Experiment

	<u>MPT Score</u>	<u>Training Time (min.)</u>	<u>Test Time (min.)</u>	<u>Control Errors</u>	
				<u>Selection</u>	<u>Adjustment</u>
Phylogenic Console					
1	29	*	*	*	*
2	32	72.5	22.4	66	90
3	48	56.5	30.0	43	94
4	49	71.0	42.1	94	275
5	50	62.3	24.2	66	206
6	57	52.5	24.7	52	57
7	57	48.8	46.5	63	156
Verbal Analysis					
1	33	*	*	*	*
2	32	75.0	20.8	15	16
3	43	*	*	*	*
4	48	65.0	20.4	21	101
5	53	89.0	41.8	64	129
6	54	76.0	26.7	46	66
7	59	72.0	22.1	35	63
Instruction Manual, Short					
1	28	75	62.8	140	398
2	35	90	56.5	138	406
3	44	60	38.7	77	200
4	47	60	25.0	143	333
5	50	40	19.6	70	102
6	58	89	41.0	154	382
7	60	90	43.9	111	233
Instruction Manual, Long					
1	29	155	57.6	68	150
2	38	104	47.8	95	289
3	45	118	61.9	89	179
4	49	86	48.7	251	725
5	52	77	29.0	103	234
6	52	85	14.1	55	44
7	60	94	31.2	73	112

*Did not complete training within three hours.

APPENDIX E

Instructions for Slide and Tape SAGE Console Task Teaching Program

As soon as the subject was seated before the console the taped introductory instructions commenced. The instructions described the task which was to be learned, the manner of presentation, and the main parts of the console. Slides were projected onto the console just above the control panel to illustrate the taped material. Six slides were used in the introductory material: one which described the various console parts, one which illustrated a typical display and described the display matrix notation, one which showed the logic flow diagram symbols, two which showed how the logic symbols were combined into flow diagrams leading from control action to control action, and one which related the sequence of displays diagram to action sequences.

Following the introductory instructions, a series of teaching frames were presented. Each frame displayed a display situation and diagrammed the acceptable alternative action sequences. The taped instructions for each frame described what the display signified, what actions to take, what the actions did, and what feedback the subject would receive if he took the correct actions. Then the subject was instructed to trace through the series of actions designated by the logic flow diagram. Taped instructions for a sample frame are reproduced below.

Frame 1

Now you will start learning to use the console during an intercept mission. A diagram of the display lights is projected on the upper screen. Study the configuration of lights in the diagram, then find where this diagram appears in the sequence of displays which is located on the middle panel. Reference to the sequence of displays helps you to follow the mission. When you have found the matching display in the sequence of displays, look at the label under the diagram, it should say ACKNOWLEDGE ASSIGNMENT. Now look at the lower projection screen. You will see a diagram connecting various pushbuttons. This logic diagram identifies the number and order of pushbuttons which are appropriate for this display.

You are required to accept and to follow the assigned mission. Four lights in row 4 of the display (lights 4B, 4C, 4C, and 4E) will go off when you have acknowledged assignment.

You have to take the following actions to acknowledge assignment:

First Step - prepare the computer by pressing the four "Clear" buttons which are designated by the unordered "and" symbol at the far left of the projected diagrams.

Second Step - activate display information mode by pressing the "Display Information" button (designated by the next ordered "and" symbol).

Third Step - acknowledge assignment by pushing the "Acknowledge Assignment" button (next on the diagram).

Fourth Step - Activate computer. Here you have to choose between two equally appropriate branches. If you select the upper branch, you will have to enter the track number by pushing four "Track Number" buttons (this stores the identification of the aircraft track you are following), then activate the computer by pushing either of the two "Activate Action" buttons. The computer will then perform the programmed steps and update the display. If, on the other hand, you choose the lower branch, after the acknowledge assignment button you use the "Light Gun" button, which also causes the computer to store the identification of the designated aircraft track. In this sequence the same results are obtained by using the light gun button, or by using the track number and activate action buttons (both methods store the track number and activate the computer).

Now, start at the left and push the buttons indicated by the logic diagram. First, push the 4 clear buttons---the order is not important. Next, push the display information button, then the acknowledge assignment button. Now you are at a choice point, select either the upper path or the lower path. Do not follow both paths. If you select the lower path, simply push the light gun button---then you are finished. If you select the upper path push the 4 track number buttons (in order) and either of the activate buttons.

If during a real mission you follow these steps correctly, the four lights in the fourth row will go off.

If during a real mission you had followed these steps the display would not change, and you would start again on the left and try to do everything correctly. Unless you wish to review this slide again, we will go on to the next display.

Twelve frames were presented, covering each alternative mission sequence. Then all the sequences were reviewed. During the review of a frame the display was projected on the upper panel but was not interpreted for the subject. He was instructed to compare it with those shown in the sequence of displays diagram, and then take the appropriate actions. After a short interval he was told the display designation and the list of appropriate actions was read. He was told to trace through these actions again as the list was repeated.

APPENDIX F

Instruction Manual for SAGE Console Task

The instruction manual covered the same information as did the slide/tape presentation. With the exception of minor wording changes, the organization and figures were exact duplicates. The same number and type of frames were presented, a sample of which appears below.

Display Number 1

	A	B	C	D	E
1	○	○	○	●	●
2	●	○	○	●	●
3	○	○	○	●	●
4	○	●	●	●	●
5	○	○	○	○	○

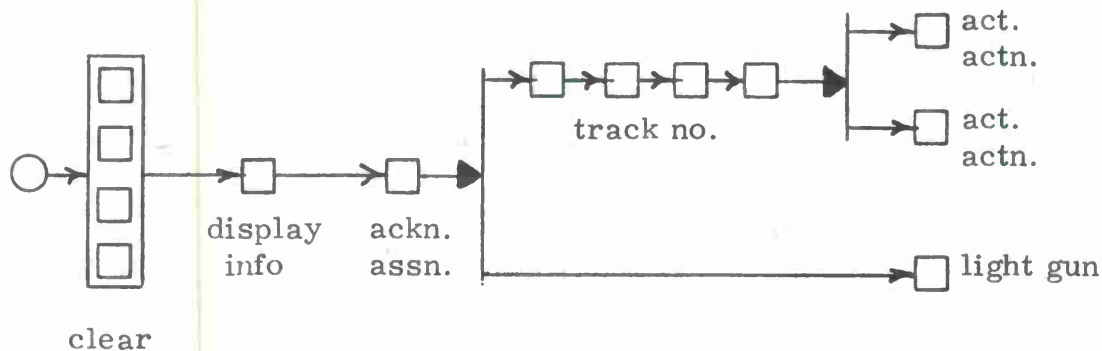
Acknowledge Assignment

Problem: Accept an assigned mission, direct computer to follow a particular aircraft radar track.

Required Actions:

1. Clear computer
2. Activate display information mode
3. Acknowledge assignment
4. Insert track number (aircraft identifying number)
5. Activate computer

Action Sequence:



Display Change:

When the operator properly accepts a mission, all lights in row 4 (4B, 4C, 4D, and 4E) go off. Other lights remain as before.

Explanation of Operation Actions:

Problem: Acknowledge Assignment

Purpose: To acknowledge a mission assignment

<u>Action</u>	<u>Purpose</u>	<u>Result</u>
1. Push CLEAR buttons (four)	To clear the computer for storage of new info	
2. Push DISPLAY INFORMATION button	To program computer to display info on the screen	Computer program remains inactive
3. Push ACKNOWLEDGE ASSIGNMENT button	To store info for the computer program	Stored info remains inactive
4. Select option a <u>or</u> b below:		
a. push TRACK NO. buttons (four)	To store Track No. of the assigned aircraft for the computer program	Stored Track No. remains inactive
AND		
either of the ACTIVATE ACTION buttons	To activate computer program to handle the stored info	Computer performs the programmed steps and updates the display
OR		
b. push LIGHT GUN button	To use the Light Gun to store Track No. and activate the computer	Same as above

The manual was 31 pages in length. On the last page, the reader is referred back to the first frame to review the sequences a second time. Since the reader was seated at the console while studying the manual, he was also told to observe the various elements of the console and relate these to the text material.

APPENDIX G

Instruction Manual for the Numbers Game

The complete instruction manual is reproduced in the following paragraphs. Note that the manual is organized to emphasize the decision points and alternative actions shown in the over-all task diagram for the game (Figure 4).

Instructions

1. General

In this game you have to determine a four digit "unknown" number through a process of logical deduction. On the sheet before you is a list of four digit test numbers (this list is called the LTN) which you will use to obtain information about the "unknown". You will select a test number from the LTN, write the code identification for this number on a 3 x 5 card, and place the card in the window of the partition beside you. A "score" will then be written on the card, and this information displayed to you. The score will tell you how many of the digits in your test number correspond (in both value and position) to digits in the "unknown" number. By keeping track of the information learned from each score, you will finally discover the digits of the "unknown". To help you keep track of the score information, there is a Possible Digits Register (PDR) and a Scores Register (SR) on the sheet of paper with the LTN. The instructions will describe how to use these aids.

2. How to Select and Submit a Test Number

For your first try, you may select any of the test numbers. Note the code identification for the test number--write this code on a 3 x 5 card and pass it through the window. After the experimenter writes the score on the card, he will show the card to you--after you have had the opportunity to see and record the score, the experimenter will keep the card. The score tells you specific bits of positive and/or negative information about the "unknown" number as well as directing your choice of subsequent test numbers. For example:

If you select the first test number (3102), write #1 (the code) on the card. If the unknown number were 4603, the score would be 1 since only the third digits (0) are identical in the two numbers. If you then select the 12th test number (3251), write #12 on the card. The score will be 0 since none of the digits correspond in both value and position with any in the unknown. Because you received a score of 1 on the first test number, you knew that one and only one of the digits was correct, but you did not know which one. Consequently, the 12th test number was selected to learn if the "3" in the first column was the correct digit. Thus, you follow up previously scored numbers by trying other numbers which have a single corresponding digit. If you had received a zero score for 3102, you would not select 3251 as the second try. In this case, you would already know that the first digit cannot be 3, so you would select a test number in which all four digits remain as "possibilities". Use test numbers which will provide the most information on each try.

3. How to Enter Zero Scores in the PDR

The Possible Digits Register (PDR) will help you keep track of which digits you rule out for each position in the "unknown" number. The "unknown" may be regarded as comprising four columns in each of which one of the digits from 1-9 or zero may appear. When you receive a zero score on a test number, the number of possible digits which could appear in each of the four columns is reduced. To keep track of those digits which have been ruled out, X out the corresponding digits in the PDR. The four columns of the PDR correspond to the four digits of the test numbers, the 10 rows of the PDR correspond to the numerical value of each digit (1-9 or zero) which can appear in any column. For example:

If your first test number is #12 (3251) and you receive a score of zero--X out 3 in the 1st column, 2 in the 2nd, 5 in the 3rd, and 1 in the 4th. The PDR would then look like this:

Columns				
1				X
2		X		
3	X			
4				
5			X	
6				
7				
8				
9				
0				

4. How to Enter Scores of 1 or 2 in the SR

The Scores Register (SR) will help you keep track of which digits probably appear in the "unknown" and should be followed up. When you receive a score of 1 or 2, simply write the complete test number in a row of the SR and the score in the same row of the score column. For example:

If your first test number is #1 (3102) and you receive a score of 1, enter these in the SR. The SR would then look like this:

Columns				Score
Test Number				
3	1	0	2	1

5. How to Update the PDR and SR

After entering the results of your first test number in either the PDR or SR, select a second test number to follow up SR cores or to rule out further possibilities in the PDR. If subsequent test numbers receive a score of zero, X out the possibilities in the PDR, then check previous entries in the SR to see if any of the digits correspond to possibilities which have now been ruled out. If any have been ruled out, you should X them out in the SR also. Then, check to see if the remaining number of digits in any row of the SR equals the score for that row. If they do, then you have identified digits in the "unknown". For example:

If your first number is #1 (3102) and is scored 2, your second test number is #12 (3251) and is scored zero, your third test number is #17 (7123) and is scored 1, and your fourth test number is #6 (7892) and is scored zero--you would have crossed out the first and last digits of 3102, leaving the number of remaining digits equal to the score (2). The PDR and SR would then look like this:

<u>PDR</u>					<u>SR</u>						
Columns					Columns				Test Number		Score
1		1	X	X	3	1	0	2			2
2		X	X	X	3	2	5	1			0
3	X	X	X	X	7	1	2	3			1
4		X	X		7	8	9	2			0
5		X	X								
6		X	X								
7	X	X	X								
8		X	X								
9		X	X								
0		X	0								

Circle positively identified digits in the SR (in this case 1 in the 2nd column, and 0 in the 3rd column), enter the identified digits in the PDR and X out possibilities which have been ruled out. Since you have identified the digits in the 2nd and 3rd columns, X out all the rest of the spaces in these columns. The remaining entries in the SR are then rechecked to X out digits in the 2nd and 3rd columns which had been crossed out in the PDR. Subsequent test numbers would then be selected to include digits in the first and fourth columns which have not yet been ruled out.

Continue to evaluate additional test numbers until you can deduce the complete "unknown" four digit number. When you know the complete number, write it on a card and pass it through the window to the experimenter. He will tell you if you are correct or write "No" on the card if you are wrong. Continue to play until you are correct.

You will play the game a predetermined number of times, or until time for the test session runs out. The object of the game is to work as quickly as possible to learn the "unknowns" with as few test numbers as possible. You may commence as soon as you feel that you understand how to proceed.

APPENDIX H

Performance Measures for the Numbers Game

All time measures are in minutes, other measures are number of queries. The submission of the correct four digit number (which terminated the game) is not included in the totals. Incorrect guesses for the "unknown" four digit number were always categorized as "no value". Subjects 1 through 6 read the instruction manual, and 7 through 12 used the logic flow diagrams.

		Task					
		Training Time	A	B	C	D	E
Total Requests for Each Subject							
1	10.0	18	13	9	12	24	15
2	13.4	17	12	13	15	13	14
3	8.4	18	14	12	14	16	14
4	8.0	13	21	19	14	11	11
5	11.0	14	17	19	14	10	15
6	12.5	12	*	20	27	14	15
7	53.0	15	16	10	*	18	20
8	5.0	12	13	11	12	11	15
9	4.0	13	10	18	20	14	12
10	17.0	17	10	13	12	11	13
11	12.0	15	12	15	13	13	13
12	24.0	14	12	17	12	12	12
Total High Value Queries							
1		9	10	8	8	9	14
2		14	12	10	12	11	13
3		7	11	8	6	9	8
4		11	9	12	12	12	11
5		8	13	10	8	7	12
6		9	*	9	12	9	9
7		12	12	9	*	9	8
8		9	9	10	8	10	11
9		9	7	12	9	14	11
10		10	10	10	8	8	12
11		11	9	12	12	10	10
12		11	9	11	12	12	12

		<u>Task</u>					
		<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>
Total Low Value Queries							
1		3	2	1	3	5	1
2		3	0	3	1	2	1
3		3	2	2	3	3	4
4		1	0	2	2	0	0
5		3	0	4	5	2	1
6		0	*	2	0	3	0
7		3	1	1	*	4	6
8		3	1	1	2	1	3
9		3	3	3	3	0	0
10		2	0	2	2	3	1
11		3	3	1	1	3	3
12		1	3	0	0	0	0
Total No Value Queries							
1		6	1	0	1	10	0
2		0	0	0	2	0	0
3		8	1	2	1	4	2
4		1	12	5	0	0	0
5		3	4	5	1	1	2
6		3	*	9	15	2	6
7		0	3	0	*	5	7
8		0	3	0	2	0	1
9		1	0	3	8	0	1
10		5	0	1	2	0	0
11		1	0	2	0	0	0
12		2	0	6	0	0	0
Total Time to Completion							
1		24.0	12.1	9.5	10.6	29.5	12.2
2		22.5	11.2	12.1	13.4	10.8	12.8
3		24.0	11.6	9.0	7.9	10.0	7.1
4		10.6	24.6	17.0	8.1	6.5	5.2
5		13.9	12.2	15.4	9.5	6.8	9.9
6		8.2	*	12.0	19.3	8.1	10.8
7		20.0	26.8	14.0	*	15.0	15.3
8		9.7	9.2	6.3	7.2	4.3	9.5
9		13.5	8.5	30.0	31.3	13.3	13.5
10		21.0	8.6	13.5	19.3	8.1	9.5
11		14.9	8.8	14.9	9.7	7.9	11.0
12		47.0	24.9	33.6	16.0	15.5	11.5

*Game was discontinued after 35 minutes and 25 queries.

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Bio-Dynamics Incorporated, 207 Bent Street Cambridge, Massachusetts		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP n/a	
3. REPORT TITLE Design & Use of Information Systems for Automated On-The-Job Training Volume III. Experimental Use of Three Instructional Concepts			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Volume III of V Volumes			
5. AUTHOR(S) (Last name, first name, initial) None			
6. REPORT DATE March 1965		7a. TOTAL NO. OF PAGES 74	7b. NO. OF REFS 10
8a. CONTRACT OR GRANT NO. AF 19 (628)-455		8a. ORIGINATOR'S REPORT NUMBER(S) ESD-TDR-64-234, Volume III	
b. PROJECT NO. 7682, Task 768204		8b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) None	
c.			
d.			
10. AVAILABILITY/LIMITATION NOTICES Copies have been deposited with the Defense Documentation Center. (DDC) DDC release to CFSTI (Formerly OTS) is authorized.			
11. SUPPLEMENTARY NOTES None		12. SPONSORING MILITARY ACTIVITY Decision Sciences Laboratory, Electronic Systems Division, Air Force Systems Command, USAF L. G. Hanscom Field, Bedford, Massachusetts	
13. ABSTRACT This report describes three experiments in which novel teaching concepts were demonstrated. These concepts had been proposed in previous reports but their effectiveness remained to be verified experimentally. The results were : 1. A teaching program ordered according to the discovery principle significantly reduced errors and performance time over that observed after training with a conventional training manual. 2. Slides projected directly onto a control console, together with a taped lecture, were found to be an effective method of presenting an automated training program. 3. Graphical logical flow diagrams were found to be efficient instructions for teaching procedures for performing a querying-reasoning task. It was concluded that these concepts should be exploited in training programs for operators of Air Force Information Systems.			

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Information Systems Design Training Devices Automation Experimental Data Computers Teaching Machines Behavior Analyses Game Theory Display Systems						

INSTRUCTIONS

1. **ORIGINATING ACTIVITY:** Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. **REPORT SECURITY CLASSIFICATION:** Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. **GROUP:** Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. **REPORT TITLE:** Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. **DESCRIPTIVE NOTES:** If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. **AUTHOR(S):** Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. **REPORT DATE:** Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. **TOTAL NUMBER OF PAGES:** The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. **NUMBER OF REFERENCES:** Enter the total number of references cited in the report.

8a. **CONTRACT OR GRANT NUMBER:** If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. **PROJECT NUMBER:** Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. **ORIGINATOR'S REPORT NUMBER(S):** Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. **OTHER REPORT NUMBER(S):** If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. **AVAILABILITY/LIMITATION NOTICES:** Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

- (1) "Qualified requesters may obtain copies of this report from DDC."
- (2) "Foreign announcement and dissemination of this report by DDC is not authorized."
- (3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."
- (4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."
- (5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. **SUPPLEMENTARY NOTES:** Use for additional explanatory notes.

12. **SPONSORING MILITARY ACTIVITY:** Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. **ABSTRACT:** Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

